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(ZHURNAL OBSHCHEI KHIMII)

IN ENGLISH TRANSLATION

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ACADEMICIAN ALEKSANDR NIKOLAEVICH NESMEYANOV

(On his 60th birthday)

N. N. Semenov, M. M. Shemyakin, and N. K. Kochetkov

Exceptional breadth of scientific interests and brilliant originality, a propensity for the solution of principal theoretical and practical problems, and a constant desire to penetrate to the very essence of the problems under investigation are characteristic traits of the creative genius of Academician Aleksandr Nikolaevich Nesmeyanov, one of the greatest organic chemists of our time, whose sixtieth anniversary is being celebrated this year by Soviet scientists.

In his great series of brilliant investigations A. N. Nesmeyanov has embraced a very wide circle of problems, ranging from the synthetic problems of heteroorganic chemistry to the preparation of new polymers of practical value, from theoretical problems of reaction mechanism and reactivity to the development of methods of synthesizing complex heterocyclic systems. It is difficult, therefore, in a short article to reveal even the main directions of the research investigations of A. N. Nesmeyanov and his large school, and it is possible to record only the chief landmarks and the most important results of his varied scientific activity, which constantly yields new, valuable results.

From the very first steps of his creative activity, A. N. Nesmeyanov showed a striving to find the proper paths in science when he devoted himself, while working in the laboratory of N. D. Zelinskii, to the solution of the problems of heteroorganic compounds, with which all of his further scientific activity has been connected to a considerable extent. As a result of this first period he developed a simple and elegant method for the synthesis of metalloorganic compounds by the use of aromatic diazo compounds, which became very well known and is now the most successful method for the synthesis of aromatic derivatives of mercury, antimony, and arsenic. This method, which bears the name of A. N. Nesmeyanov, is employed everywhere now in preparative organic chemistry. The synthetic side of the chemistry of metalloorganic compounds also was vigorously developed by A. N. during subsequent years. He and his school studied the numerous reciprocal conversions of aromatic metalloorganic compounds and as a result they developed methods for the synthesis of aromatic derivatives of tin, zinc, thallium, aluminum, and other metals, and also methods for the preparation of organomercury compounds from compounds of tin, lead, mercury, antimony, cadmium, thallium, etc.

A characteristic trait of all of A. N. Nesmeyanov's creative activity is the continuous connection of the solution of theoretical and synthetic problems. It must be noted that the chemistry of the heteroorganic compounds is particularly rich in possibilities for investigation on ample synthetic material of the general problems of organic chemistry. Hence, it is no accident that the heteroorganic compounds were the favorite objects of investigation for A. N. and that his research presents a classic example of the utilization of synthetic chemistry for the solution of principal theoretical problems.

Having started with the elucidation of the mechanism of formation of metalloorganic compounds and established the homolytic nature of the decomposition of diazo compounds under the influence of metals, A. N. widened the circle of his investigations devoted to homolytic reactions in solution, and moved on to the study of other onium compounds. Since that time the chemistry of the latter has been one of the favorite fields of A. N., which he is successfully exploiting even now. This cycle of investigations began with the study of iodonium compounds, for which he found an original method of synthesis from organomercury compounds. In recent years A. N. Nesmeyanov has developed methods of synthesis for bromonium and chloronium compounds

and, finally, for aromatic oxonium compounds by way of the arylation of bromo- and chlorobenzene and diphenyl ether with diazonium borofluorides. Development of the synthesis of these unique compounds was an outstanding achievement of organic chemistry in recent years and was a result of A. N. Nesmeyanov's systematic study of the mechanism of the homolytic and heterolytic decomposition of diazo compounds. As in a number of other investigations starting with synthetic research, A. N. then went on to an intensive study of the mechanism of decomposition of onium compounds, showing on a large amount of experimental material the path both of their homolytic decomposition (taking place, for example, under the influence of metals) and of their heterolytic decomposition (for example, under the influence of amines).

Another line in heteroorganic chemistry that has occupied an important place in A. N. Nesmeyanov's research is the investigation of metalloorganic compounds obtained by the addition of metals to unsaturated compounds of the olefin and acetylene series, characterized by two types of metal reactions — those in which the carbon bond is preserved and those where it is ruptured. Of particular interest were the addition products of the metal halides and acetylene, and here again the synthetic methods developed by A. N. served only as a prelude to the solution of the most important problem of the stereochemical relationships in β-chlorovinyl metalloorganic compounds. Having carried out a wide range of reactions of reciprocal exchange of the metal atom in compounds of mercury, antimony, thallium, lead, and tin containing the β-chlorovinyl radical, A. N. showed that such an exchange takes place without inversion of the configuration on the carbon having the double bond. This rule is the first, and up to the present time almost the sole general law relating to the dynamic stereochemistry of geometric isomers; in this field it is of fundamental significance.

Investigation of addition reactions to other unsaturated compounds — the vinyl ethers — led A. N. to the development of a method of synthesizing previously unknown α-mercurated carbonyl compounds. A study of the exchange of the metal atom in them revealed interesting rules that led to the preparation of C- or O-substituted derivatives. These data served as a starting point for the elucidation of the problem of the reactivity of metallic derivatives of carbonyl-containing systems, a problem that has occupied the minds of organic chemists since the second half of the last century. Comparing data obtained in a study of the reactions of mercurated carbonyl derivatives, on the one hand, and of alkali metal derivatives of some carbonyl and β-dicarbonyl systems, on the other hand, A. N. developed a new idea of dual (multiple) reaction capacity and the transference of the reaction center in the reactions of metal derivatives. Separation of the geometric isomers of the magnesium and lithium enolates of diphenylpropiomesitylene and some other facts permitted him to refute the speculative hypotheses prevailing in theoretical organic chemistry (tautomerism of metallic derivatives, ion mesomerism of β-dicarbonyl compounds) and made it possible for the first time to establish on a firm experimental foundation our ideas of the structure and reactivity of metallic derivatives. The simultaneously developed ideas of σ, π- and σ, σ-linkages permitted the clear formulation of the well-known alkylation reaction on the carbon of acetoacetic ester and similar compounds as a reaction that takes place with a transfer of the reaction center.

The ideas of dual reactivity and transfer of the reaction center brought clarity into the maze that existed in questions of tautomerism and reactivity — now these phenomena appear connected with each other but rather clearly delimited. The development and the experimental foundation of these ideas together with the broadening of our understanding of conjugation are a substantial contribution of A. N. Nesmeyanov to theoretical organic chemistry and continue the old traditions of Russian chemical science, which since the times of Butlerov and Markovnikov has continuously given primary significance to general theoretical problems of organic chemistry.

Another no less important theoretical problem whose solution was first given serious attention in A. N. Nesmeyanov's laboratory is the question of the mechanism of electrophilic displacement on a saturated carbon atom. Using the previously developed method for the preparation of α-mercurated carboxylic acids, he succeeded for the first time in obtaining diastereomeric L-menthyl esters of α-bromomercuriphenylacetic acids. Investigations of the symmetrization reaction of the latter and the reverse reaction of desymmetrization of the symmetric derivatives made possible for the first time a conclusion as to the stereochemical course of the reaction of electrophilic displacement on a saturated carbon atom, at the same time opening up an important new field for further investigation.

It can be seen from this short account of the research of A. N. Nesmeyanov devoted to the chemistry of heteroorganic compounds that here there are embraced almost all the most important types of metalloorganic and heteroorganic compounds, and that this material has served as a basis for the solution of a number of theoretical problems of primary importance.

Aleksandr Nikolaevich Nesmeyanov

The Editorial Board of the "Journal of General Chemistry" warmly
congratulates the great organic chemist, Academician Aleksandr
Nikolaevich Nesmeyanov on the sixtieth anniversary of his birth
and the thirty-fifth anniversary of his outstanding scientific, pedago-
gical, and social activity, and wishes him good health for many
years and further fruitful work for the good of his motherland and
soviet science.

Together with his study of "classical" metalloorganic compounds containing a covalent carbon — metal bond, A. N. has given much attention to a new, recently discovered type of metalloorganic compounds that are formed as a result of the utilization of the s, p, d-electrons of the transition elements and the π-electrons of unsaturated bonds, first and foremost the so-called metallocenes. These derivatives of cyclopentadiene, which have aromatic properties, are of great interest. A. N. Nesmeyanov's laboratory has directed its energies toward the chemical investigation of the most important representative of this class, ferrocene, which is obtained by the reaction of cyclopentadienylmagnesium chloride with ferric chloride. At the time that these investigations were started there was practically no information on the properties and reactions of ferrocene, and therefore A. N.'s studies were directed first of all to a thorough investigation of the substitution reactions of this unusual compound. A wide range of reactions was investigated — alkylation, arylation, sulfonation, metallation, amination, and condensation with carbonyl compounds, as a result of which a tremendous number of derivatives of ferrocene were prepared. The experimental material clearly demonstrated the aromaticity of ferrocene, making it possible to develop a number of unique properties of this compound and to determine its place among other aromatic systems. At the present time, A. N. is occupied with the solution of the central problem of ferrocene chemistry, questions of the orientation when substituents enter, which in its turn will elucidate the question of the transmission of effect between two five-membered rings through a central iron atom. To solve these problems in the laboratory A. N. has developed a method for the destruction of the extremely stable ferrocene nucleus by catalytic hydrogenation, which aids in the determination of the position of substituents.

A. N.'s vast research in the field of heteroorganic compounds and also his accumulation of voluminous factual material permitted him recently to make a number of broad generalizations concerning the tendency to formation, the stability, and the reactivity of heteroorganic compounds. These generalizations, which embrace the whole periodic system, were stated by A. N. in 1959 in his report on problems at the VIII th Mendeleev Congress. They have cardinal significance for chemistry as a whole, connecting together many problems of the chemistry of heteroorganic compounds that at first glance seem diverse.

It should be particularly emphasized that the breadth of the chemical interests of A. N. has often led him to the solution of many important questions that go beyond the limits of metalloorganic chemistry, although these questions usually result from problems that are in some degree connected with the chemistry of hetero-organic compounds. Thus, the desire to find an analogy to the unusual behavior of the metalloorganic β-chloro-vinyl compounds among purely organic materials led to a cycle of investigations connected with the chemistry of β-chlorovinyl ketones. Although the analogy referred to was not found, still some very fruitful synthetic in-vestigations were widely developed on the basis of the highly reactive β-chlorovinyl ketones. After the develop-ment of a method for the preparation of β-chlorovinyl ketones by the condensation of acid chlorides with acetylene, these compounds served as very convenient material for simple and elegant syntheses of numerous new classes of aliphatic (various substituted β-vinyl ketones, and acetals of β-ketoaldehydes), alicyclic (bicycloheptane de-rivatives), aromatic (styryl ketones, naphthalene derivatives, and salicylic acids), and especially heterocyclic compounds (derivatives of pyrazole, isoxazole, triazole, and pyridine, and salts of pyrrole, flavole, naphtho-pyrrole, quinolizine, azaquinolizine, etc.). The new methods developed for the synthesis of numerous types of compounds demonstrate the multiple significance of the β-chlorovinyl ketones in organic synthesis.

Almost simultaneously A. N. started the development of another large field of organic synthesis connected with the utilization of the telomerization reaction, which quickly led to very important practical results. In-tensive study of this reaction, which at the start of A. N.'s project had been almost uninvestigated, quickly made available a wide range of compounds, and first of all the ω-chlorotrichloromethylalkanes; but a study of their numerous and complex transformations then made possible the development of new, simple methods of synthesis of classes of compounds previously completely unknown or not very available, first and foremost the different substituted carboxylic acids. Of greatest interest was the preparation by this new method of amino acids, among them the natural α-amino acids. In this cycle of research we see the constant striving of A. N. to find a way to the practical utilization of the results that he obtained, which in this case brought the merited great success. An interest in the chemistry of high polymers directed his investigations toward the study of the possibilities of utilizing the amino acids, which had become available as a result of the use of the telomerization process, to produce artificial fiber. From ω-chlorotrichloromethylheptane there was prepared by hydrolysis and amination ω-aminoenanthic acid, the polycondensation of which yielded high molecular weight products that served for the production of a new valuable fiber, enanth. Now this process has been exploited technologically in detail and handed over to industry. At the same time a series of other conversion products of telomers have found

practical use in the production of valuable synthetic high polymers, plasticizers, perfumes, etc. The great success achieved by A. N. Nesmeyanov and the group of chemists under his leadership worthily crowns the tremendous synthetic research carried out in the thorough investigation of the telomerization reaction.

In a short article, it is difficult to include even the principal directions of the rapidly and continuously developing investigations of A. N. Nesmeyanov. Thus, we can only mention the interesting work on the synthesis of esters of the ortho acids of some elements (titanium, zirconium, and others), which upon partial hydrolysis yield polymers similar to the silicones; new work on the synthesis of organomercury compounds from hydrazones; interesting work on organoboron compounds, and many others. However, the brief list that has been presented of the principal directions of his work shows how thoroughly and deeply, and with what astounding internal logic A. N. and his school have developed, branched, and interwoven all the sometimes apparently distant problems, so that they mutually supplement each other.

*   *   *

Aleksandr Nikolaevich Nesmeyanov was born in Moscow on September 9, 1899. In 1922 he finished his course in the physicomathematical faculty of Moscow State University and since then he has been continuously connected with this very old educational institution. Here he progressed from assistant to director of one of the largest departments of MSU, the Department of Organic Chemistry, which he has headed since 1945. From 1947 through 1952, A. N. occupied the post of rector of MSU and under his direct leadership the remarkable new building of the university was planned and built on the Lenin Hills. A. N. Nesmeyanov is a brilliant teacher who has educated numerous students, many of whom are now independently heading big scientific groups and courses. A remarkable lecturer, A. N. knows how to present the most complex problem to the listeners in easy, elegant and attractive form. His lectures, which for many years have attracted a huge audience, are distinguished by their depth of content and simplicity of form, constantly acquainting the listeners with the latest news in organic chemistry and with the most exciting problems in natural science.

Side by side with Moscow University, no less a place in the life and scientific creative activity of Aleksandr Nikolaevich is occupied by the Academy of Sciences of the USSR, of which he was made an active member in 1943. From 1938 through 1954, A. N. headed the Institute of Organic Chemistry of the Academy of Sciences of the USSR, and since 1954 he has headed the Institute of Heteroorganic Compounds of the Academy of Sciences of the USSR which was created by him and his students primarily on the basis of the lines investigated by them. In 1946-1948, Aleksandr Nikolaevich Nesmeyanov occupied the post of academician-secretary of the Division of Chemical Sciences of the Academy of Sciences of the USSR, and in 1951 he was selected as president of the Academy of Sciences of the USSR and has since directed all of its activities.

Scientist Communist Aleksandr Nikolaevich Nesmeyanov has successfully combined his tremendous scientific, organizational, and pedagogical work with very great social-political activity. Since 1947, A. N. has headed the Committee on Lenin (previously Stalin) Prizes in the field of science. He has repeatedly been elected deputy of the Supreme Soviet of the RSFSR and the USSR, and has been elected vice chairman of the Supreme Soviet of the RSFSR.

The Party and the Government of the Soviet Union value highly the activity of A. N. Nesmeyanov on behalf of the welfare of the soviet nation and have rewarded him with the orders of Lenin and the Red Challenge Banner and have awarded him the Stalin Prize of the first degree in science.

The greatest Soviet scientist, whose name is known throughout the world, Academician Aleksandr Nikolaevich Nesmeyanov, who is in the bloom of his creative forces, is giving all his exceptional energy and all his tremendous talent to the welfare of our great native land.

VINYL ESTERS OF SULFONIC ACIDS

A. N. Nesmeyanov, I. F. Lutsenko, R. M. Khomutov,
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It has been known that the only products of the reaction of carboxylic acid halides with a halomercuri-acetaldehyde or halomercuriketones are the acetates of the enol forms of the oxo compounds [1]. This reaction was further utilized for the synthesis of vinyl esters of various carboxylic acids [2]. However, it also had definite limitations, for example, chlorocarbonic ester, acid chlorides of sulfonic acids, and silicon tetrachloride did not react with halomercurioxo compounds. It was found that mercuribisacetaldehyde $Hg(CH_2CHO)_2$ [3] prepared by us was much more reactive than chloromercuriacetaldehyde, and this made it possible to carry out a reaction with the acid chlorides of sulfonic acids according to the following equation:

$$RSO_2Cl + Hg(CH_2CHO)_2 \rightarrow RSO_2OCH{=}CH_2 + ClHgCH_2CHO$$

The chloromercuriacetaldehyde formed in this way does not react further. Mercuribisketones also can react like mercuribisacetaldehyde. In carrying out the reaction of mercuribisacetaldehyde with the acid chlorides of sulfonic acids it is necessary to add pyridine, since otherwise the vinyl ester of the sulfonic acid will polymerize. It also is necessary to carefully wash the reaction solution free of mercury salts, which can cause polymerization of the compound under distillation conditions. When these conditions were maintained, it was possible to obtain the vinyl esters of methane- and ethanesulfonic acids in 45 and 47% yields, respectively; the yields of the vinyl esters of benzene- and p-toluenesulfonic acids amounted to 70 and 75%, respectively.

Thionyl chloride and sulfuryl chloride also were reacted with mercuribisacetaldehyde. The first of these formed divinyl sulfite in 45% yield. The compound proved to be a very strong lachrymator. Sulfuryl chloride decomposed under the reaction conditions, giving off sulfur dioxide; divinyl sulfate was not obtained in this reaction even in small amounts.

The reaction of the vinyl esters of sulfonic acids with acyl chlorides in the presence of aluminum chloride also has been investigated. In 1951, Sieglitz and Horn [4] found that when vinyl acetate reacts with acid chlorides in the presence of aluminum chloride, 1,3-diketones are formed in moderate yields. By carrying out the reaction of vinyl benzenesulfonate with benzoyl chloride under similar conditions we obtained a high yield of β,β-dichloro-propiophenone, the formation of which we suggested was explained by the following reaction mechanism: initially the benzoyl chloride in the presence of the aluminum chloride adds at the double bond of the vinyl ester, and then this compound breaks down under the influence of the aluminum chloride:

$$C_6H_5SO_2OCH{=}CH_2 \xrightarrow{+ClCOC_6H_5}$$

$$\longrightarrow C_6H_5SO_2OCHClCH_2COC_6H_5 \xrightarrow{+AlCl_3} C_6H_5SO_2OAlCl_2 + C_6H_5COCH_2CHCl_2$$
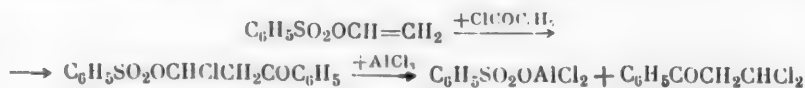
For evidence of such a mechanism we undertook experiments to isolate the intermediate product of the addition of benzoyl chloride to vinyl p-toluenesulfonate — α-chloro-β-benzoylethyl-p-toluenesulfonate. Carrying out the reaction with cooling, we were able to obtain a small yield of this compound, since even with

slight heating of the reaction mixture only β,β-dichloropropiophenone is obtained. The isolated intermediate reaction product, α-chloro-β-benzoylethyl-p-toluenesulfonate, upon heating with an equivalent amount of aluminum chloride was converted to β,β-dichloropropiophenone. When vinyl benzenesulfonate was reacted with butyl chloride, we obtained a 50% yield of a compound with b. p. 52-53° (0.5 mm), close in its analysis to the expected propyl-β,β-dichloroethyl ketone. However, because of its instability we were not able to isolate it in analytically pure form.

EXPERIMENTAL

1. Vinyl esters of benzene- and p-toluenesulfonic acids. To a warm solution (45-50°) of 145 g (0.5 mole) of mercuribisacetaldehyde in a mixture of 100 ml of dry dichloroethane and 40 g of dry pyridine was added over the course of 20-30 minutes, with stirring, a solution of 88 g (0.5 mole) of benzenesulfonyl chloride in 50 ml of dichloroethane. In a half hour the reaction mixture was cooled to room temperature, and the precipitate of chloromercuriacetaldehyde was separated off and washed with dichloroethane (2 × 15). The dichloroethane solutions were combined and then washed twice with water, twice with 1% hydrochloric solution, twice with sodium bicarbonate solution, and again with water. The solution was dried over calcium chloride. The dichloroethane was distilled off and the remaining material was distilled in vacuo. The turbid distillate (with traces of metallic mercury) was filtered and again distilled. We obtained 66 g (70%) of vinyl benzenesulfonate as a colorless liquid.

B. p. 102° (2 mm), $n^{20}D$ 1.5171, d^{20}_4 1.2292, MR_D 45.41; Calc. 45.33.

Found %: C 52.00, 52.06; H 4.36, 4.33. $C_8H_8O_3S$. Calculated %: C 52.10; H 4.38.

In a similar manner we obtained from 72 g (0.25 mole) of mercuribisacetaldehyde and 50 g (0.25 mole) of p-toluenesulfonyl chloride 38.5 g (75%) of vinyl p-toluenesulfonate.

B. p. 110° (2 mm), 124° (6 mm), $n^{20}D$ 1.5208, d^{20}_4 1.1821, MR_D 49.87; Calc. 49.95.

Found %: C 55.01, 54.71; H 5.26, 5.24. $C_9H_{10}O_3S$. Calculated %: C 54.53; H 5.09.

2. Vinyl esters of methane- and ethanesulfonic acids. To 60 g of mercuribisacetaldehyde in 150 ml of isopentane was added 15.8 g of dry pyridine, and over a period of a half-hour a solution of 22.5 g of methanesulfonyl chloride in 50 ml of isopentane was added dropwise. After 2 hours stirring the precipitate was separated and the pentane was distilled off. Upon distillation in vacuo, we obtained 12.5 g (45%) of vinyl methanesulfonate.

B. p. 78° (6 mm), $n^{20}D$ 1.4304, d^{20}_4 1.2280, MR_D 25.67; Calc. 25.84.

Found %: C 29.55, 29.71; H 5.00, 5.01. $C_3H_6O_3S$. Calculated %: C 29.49; H 4.95.

In a similar manner we obtained from 60 g of mercuribisacetaldehyde and 25.7 g of ethanesulfonyl chloride 11.5 g (42%) of vinyl ethanesulfonate.

B. p. 88° (8 mm), $n^{20}D$ 1.4341, d^{20}_4 1.1784, MR_D 30.10; Calc. 30.45.

Found %: C 34.87, 34.96; H 5.92, 5.96. $C_4H_8O_3S$. Calculated %: C 35.28; H 5.92.

3. Divinyl ester of sulfurous acid. To a suspension of 124 g (0.45 mole) of mercuribisacetaldehyde and 250 ml of isopentane was added dropwise, with stirring, 23 g (0.2 mole) of thionyl chloride. The reaction mixture was stirred for 2 hours, then the precipitate was separated out and the solvent was distilled off. Upon distillation of the residue we obtained 11.5 g (45%) of divinyl sulfite.

B. p. 127°, 78° (135 mm), $n^{20}D$ 1.444, d^{20}_4 1.1374, MR_D 31.33; Calc. 31.61.

Found %: C 36.14, 36.09; H 4.71, 4.57. $C_4H_6O_3S$. Calculated %: C 35.81; H 4.55.

4. Reaction of vinyl sulfonates with benzoyl chloride. a) β,β-Dichloropropiophenone. To a solution of 5.3 g of benzoyl chloride in 50 ml of dry carbon tetrachloride, cooled with ice, was added 5.1 g of anhydrous aluminum chloride, and then 7 g of vinyl benzenesulfonate was added dropwise. The reaction mixture was heated for 2 hours on a water bath, cooled, and decomposed with cold 5% hydrochloric acid solution. The organic layer was separated off, washed with water and with sodium bicarbonate solution, and dried over calcium

chloride. The solvent was distilled off; the remaining oil crystallized. Yield 6.7 g (88%). Colorless crystals with m. p. 53° (from petroleum ether).

Found %: C 53.25, 53.39; H 4.10, 3.96; Cl 34.89, 35.03. $C_9H_8OCl_2$. Calculated %: C 53.35; H 3.97; Cl 34.92.

b) α-Chloro-β-benzoylethyl-p-toluenesulfonate. To a solution of 5 g of benzoyl chloride in 40 ml of dry carbon tetrachloride, cooled with ice, was added 4.75 g of anhydrous aluminum chloride. Then there was added dropwise, with continuous stirring, 7.05 g of vinyl p-toluenesulfonate, and the mixture was stirred for 1.5 hours. The mixture was decomposed with cold 5% hydrochloric acid solution. The organic layer was washed with water and sodium bicarbonate solution and dried over calcium chloride. The solvent was evaporated and the solid compound was crystallized from alcohol and petroleum ether. Yield 0.75 g (6.3%). White crystalline compound with m. p. 108°.

Found %: C 56.58, 56.79; H 4.64, 4.59. $C_{16}H_{15}O_4SCl$. Calculated %: C 56.71; H 4.46.

c) β,β-Dichloropropiophenone from α-chloro-β-benzoylethyl p-toluenesulfonate. To a solution of 1.78 g of α-chloro-β-benzoylethyl p-toluenesulfonate in 40 ml of carbon tetrachloride was added 0.7 g of anhydrous aluminum trichloride. The reaction mixture was heated for 2 hours on a water bath, cooled, and decomposed with cold 5% hydrochloric acid solution. The organic layer was washed with water and sodium bicarbonate solution and dried over calcium chloride. Upon evaporation of the solvent we obtained 0.74 g (70%) of β,β-dichloropropiophenone with m. p. 52.

SUMMARY

A method has been proposed for the synthesis of vinyl esters of sulfonic acids and their reaction with acyl halides in the presence of aluminum chloride has been studied.

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THE POSSIBILITY OF PREPARING SOME ORGANOSILICON COMPOUNDS WITH ALKYLBENZYL RADICALS FROM CHLOROMETHYLATED ALKYLBENZENES

N. S. Nametkin, A. V. Topchiev, Ku Ch'ang-li, and N. A. Pritula

The reaction of chloromethylation has been studied under various conditions by a number of investigators [1-4]. They have shown the possibility of chloromethylation of aromatic hydrocarbons in aqueous medium and in acetic acid medium. As catalysts for the reaction,the use of zinc, aluminum, and tin chlorides and phosphoric and sulfuric acids has been recommended. Formaldehyde can be used in the reaction in the form of its polymer or its aqueous solution. The use of chloromethyl ester in chloromethylation also has been proposed.

We have chloromethylated toluene and ethyl- and isopropylbenzene.

$$RC_6H_5 + HCHO + HCl \rightarrow RC_6H_4CH_2Cl + H_2O,$$
$$\text{where } R=CH_3,\ C_2H_5,\ iso\text{-}C_3H_7.$$
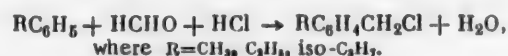
The reaction was carried out by the following general method: hydrogen chloride was passed through a mixture of alkylbenzene, 35% formalin, and zinc chloride with stirring for an hour and a half at room temperature and then for 10 hours at 70-80°. The properties and yields of the chloromethylated alkylbenzenes are given in Table 1.

TABLE 1
Properties of Chloromethylated Alkylbenzenes

Compound	Boiling point (Pressure in mm)	d_4^{20}	n_D^{20}	MR$_D$		Yield (in %)
				found	calc.	
$CH_3C_6H_4CH_2Cl$	73—75 (6)	1.0700	1.5362	40.98	40.45	54
$C_2H_5C_6H_4CH_2Cl$	78—79 (6)	1.0433	1.5300	45.75	45.08	32
iso -$C_3H_7C_6H_4CH_2Cl$	94—96 (7)	1.0192	1.5222	50.44	49.73	26

From the chloromethylated alkylbenzenes we prepared the organomagnesium compounds, which upon reaction with alkylhalosilanes formed organosilicon compounds with alkylbenzyl radicals on the silicon atom.

$$R_3SiCl + R'C_6H_4CH_2MgCl \rightarrow R'C_6H_4CH_2SiR_3 + MgCl_2,$$
$$R_2SiCl_2 + 2R'C_6H_4CH_2MgCl \rightarrow (R'C_6H_4CH_2)_2SiR_2 + 2MgCl_2,$$
$$\text{where : } R=CH_3,\ C_2H_5;\ R'=CH_3,\ C_2H_5,\ iso\text{-}C_3H_7.$$
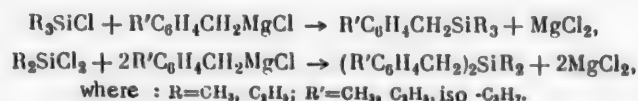
By the reaction of methyltoluenemagnesium chloride and methylethylbenzenemagnesium chloride with diethyldichlorosilane and subsequent decomposition of the reaction mass with water we prepared the alkyl-benzyldiethylsilanols in 42% yield in both cases, along with silicohydrocarbons.

$$(C_2H_5)_2SiCl_2 + RC_6H_4CH_2MgCl \rightarrow RC_6H_4CH_2\underset{\underset{C_2H_5}{|}}{\overset{\overset{C_2H_5}{|}}{Si}}\!-\!Cl + MgCl_2 \xrightarrow{H_2O}$$

$$\longrightarrow RC_6H_4CH_2\underset{\underset{C_2H_5}{|}}{\overset{\overset{C_2H_5}{|}}{Si}}\!-\!OH + HCl,\ \text{where:}\ R=CH_3,\ C_2H_5.$$
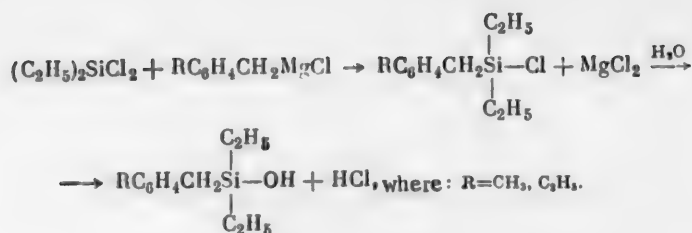
Methylbenzyldiethylsilanol condensed upon standing to 1,3-di(methylbenzyl)-1,1,3,3-tetraethyldisiloxane.

$$2CH_3C_6H_4CH_2\underset{\underset{C_2H_5}{|}}{\overset{\overset{C_2H_5}{|}}{Si}}\!-\!OH \xrightarrow{H_2O} CH_3C_6H_4CH_2\!-\!\underset{\underset{C_2H_5}{|}}{\overset{\overset{C_2H_5}{|}}{Si}}\!-\!O\!-\!\underset{\underset{C_2H_5}{|}}{\overset{\overset{C_2H_5}{|}}{Si}}\!-\!CH_2C_6H_4CH_3$$
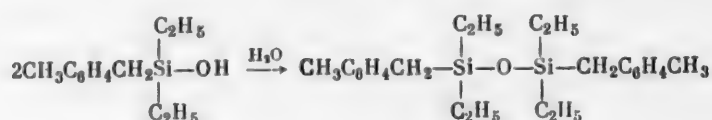
The properties of the silicohydrocarbons and the oxygen-containing compounds with alkylbenzyl radicals that were obtained are given in Table 2.

TABLE 2

Physicochemical Properties of Organosilicon Compounds with Alkylbenzyl Radicals

Compound	Boiling point (Pressure in mm)	d_4^{20}	n_D^{20}	MR_D		Found		Calculated	
				found	calc.	C	H	C	H
CH₃C₆H₄CH₂Si(CH₃)₃	80—80.5°(11)	0.8729	1.4964	59.71	59.15	74.32, 74.21	10.16, 10.24	74.02	10.11
CH₃C₆H₄CH₂Si(C₂H₅)₂OH	119—124 (5)	—	—	—	—	—	—	—	—
[CH₃C₆H₄CH₂Si(C₂H₅)₂]₂O	219—220 (4)	0.9650	1.5238	123.50	125.18	72.44, 72.47	9.88, 9.82	72.04	9.81
(CH₃C₆H₄CH₂)₂Si(C₂H₅)₂	183—185 (5)	0.9727	1.5445	96.29	97.28	80.39, 80.21	9.55, 9.58	80.01	9.50
(C₂H₅C₆H₄CH₂)₂Si(C₂H₅)₂	175—177 (4)	0.9538	1.5410	106.91	106.54	81.15, 81.28	9.97, 9.81	81.45	9.93
C₂H₅C₆H₄CH₂Si(C₂H₅)₂OH	134—136 (6)	0.9629	1.5140	69.50	68.95	70.19, 70.16	9.92, 9.89	70.23	9.98
iso -C₃H₇C₆H₄CH₂Si(CH₃)₃	101—103 (9)	0.8685	1.4916	68.88	68.41	75.60, 75.95	10.75, 10.63	75.68	10.71
(iso -C₃H₇C₆H₄CH₂)₂Si(CH₃)₂	165—166 (4)	0.9376	1.5324	107.54	106.54	81.46, 81.50	10.10, 10.07	81.45	9.93
(iso -C₃H₇C₆H₄CH₂)₂Si(C₂H₅)₂	193—194 (3)	0.9378	1.5350	117.04	115.80	81.47, 81.38	10.45, 10.58	81.75	10.30

For a long time it had been thought that when alkylbenzenes were chloromethylated, only p-chloromethyl-alkylbenzenes were obtained. However, there were indications [2, 4] that when toluene was chloromethylated the ortho-isomer also was formed along with the para-isomer. At the time that the present work was completed, the investigations of Nazarov and Semenovskii [5] were published, in which it was shown for the first time that the ortho- and para-isomers are formed not only in the chloromethylation of toluene, but also in the chloromethylation of ethyl- and isopropylbenzenes. To establish the quantitative ratio of the ortho- and para-isomers in the chloromethylalkylbenzenes, the authors carried out their oxidation with chromic anhydride. Under these conditions o-chloromethylalkylbenzenes are completely broken down, but the p-chloromethylalkylbenzenes are oxidized to terephthalic acid. When pure p-chloromethyltoluene was oxidized, terephthalic acid was formed in 81% yield. The para-isomer content was calculated by comparing the yields of terephthalic acid formed by the oxidation of pure p-chloromethyltoluene and of the chloromethylated alkylbenzenes.

In this connection, we were interested in studying the structure of the organosilicon compounds with alkylbenzyl radicals obtained from the chloromethylated benzenes, and in their turn the structure of the chloromethylalkylbenzenes themselves.

The structure of the former was established by oxidation by a method suggested by Nazarov and Semenovskii. Under the conditions adopted for the oxidation, terephthalic acid was formed in different yields. From Table 3, it is seen that the oxidized products contained both p- and o-alkylbenzyl radicals; thus, if we compare Experiments 2, 3, and 6, it can be noted that as the alkyl radical in the alkylbenzyldiethylsilanes became larger the para-isomer content increased. When di(isopropylbenzyl)diethylsilane was oxidized, the yield of terephthalic acid reached 79%. This provides a basis for the conclusion that the di(isopropylbenzyl)diethylsilane obtained contained for practical purposes only p-isopropylbenzyl radicals.

TABLE 3
Yields of Terephthalic Acid Upon
Oxidation of Organosilicon Compounds

Expt. No.	Compound	Yield of terephthalic acid (in %)
1	$CH_3C_6H_4CH_2Si(CH_3)_3$	54
2	$(CH_3C_6H_4CH_2)_2Si(C_2H_5)_2$	53
3	$(C_2H_5C_6H_4CH_2)_2Si(C_2H_5)_2$	75
4	iso-$C_3H_7C_6H_4CH_2Si(CH_3)_3$	70
5	(iso-$C_3H_7C_6H_4CH_2)_2Si(CH_3)_2$	73
6	(iso-$C_3H_7C_6H_4CH_2)_2Si(C_2H_5)_2$	79
7	$C_2H_5C_6H_4CH_2Si(C_2H_5)_2OH$	43
8	$[CH_3C_6H_4CH_2Si(C_2H_5)_2]_2O$	46

TABLE 4
Ratio of Para- and Ortho-Isomers in
Chloromethylalkylbenzenes

Compound	Content of isomers (in %)	
	para	ortho
$CH_3C_6H_4CH_2Cl$	60	40
$C_2H_5C_6H_4CH_2Cl$	70	30
iso-$C_3H_7C_6H_4CH_2Cl$	90	10

The structure of the chloromethyl derivatives of the alkylbenzenes was investigated by reducing them through the organomagnesium compounds to the corresponding methylalkylbenzenes and determining the Raman spectra of the latter.* In the spectra we found two nonoverlapping lines close together, with equal blackening, belonging to the different isomers. Knowing the table values for the intensities of these lines for the individual hydrocarbons [6], we determined the relative content of the isomers in the chloromethylalkylbenzenes (Table 4).

The data obtained on the ratio of para- and ortho-isomers formed on chloromethylation of the ethyl- and isopropylbenzenes agreed well with data obtained by Nazarov and Semenovskii. It should be noted, however, that in the chloromethylation product of toluene we found the para-isomer in rather small amounts. The chloromethylation was carried out by Nazarov and Semenovskii in aqueous medium at 50° without a catalyst, and by us at 70-80° in the presence of zinc chloride. The data obtained on the ratio of the para- and ortho-isomers of chloromethyltoluene agreed well with the data of Hill [7] established by thermal analysis. It should be noted that Hill carried out the chloromethylation by the method of Blanc [8] under conditions close to those used by us.

EXPERIMENTAL

A. Syntheses based on toluene. 1. Chloromethyltoluene. In a three-necked flask equipped with a stirrer, reflux condenser, thermometer, and a tube for passing through hydrogen chloride were placed 92 g (1 mole) of toluene, 130 g (1.5 moles) of 35% formalin, and 25 g of zinc chloride. Hydrogen chloride was passed through the reaction mixture for 1.5 hours at room temperature and then for 10 hours at 70-80°. After the mixture was cooled, the organic layer was separated, washed to a neutral reaction, dried with calcium chloride, and subjected to fractionation. We obtained 76 g (54%) of chloromethyltoluene.

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* The Raman spectra were determined by V. V. Bazilevich on a three-prism glass spectrograph with a cell for which $f = 270$ mm.

2. Methylbenzyltrimethylsilane. To the organomagnesium compound prepared from 12 g (0.5 g-atom) of magnesium and 60 g (0.43 mole) of chloromethyltoluene was added 42 g (0.39 mole) of trimethylchlorosilane. The mixture was heated for 8 hours. Yield 22 g (32%).

3. Di(methylbenzyl)diethylsilane. To the organomagnesium compound prepared from 19 g (0.77 g-atom) of magnesium and 84.5 g (0.61 mole) of chloromethyltoluene was added 47 g (0.3 mole) of diethyldichlorosilane. The mixture was heated for 10 hours. Yield 23 g (26%). On fractionation, methylbenzyldiethylsilanol also was isolated in the amount of 26 g (41.6%), and condensed on standing to 1,3-di(methylbenzyl)-1,1,3,3-tetraethyldisiloxane.

4. Oxidation of methylbenzyltrimethylsilane. To a mixture of 2.58 g (0.0145 mole) of methylbenzyltrimethylsilane, 20 ml of 98% sulfuric acid, 60 ml of glacial acetic acid, and 60 ml of water was slowly added 70 g of chromic anhydride. The mixture was heated for 2 hours at 90-100°. We obtained 1.29 g (54%) of terephthalic acid, which indicated the presence of 68% para-isomer.

5. Oxidation of 1,3-di(methylbenzyl)-1,1,3,3-tetraethylsiloxane. To a mixture of 3.91 g of compound, 30 ml of 98% sulfuric acid, 100 ml of glacial acetic acid, and 100 ml of water was slowly added 120 g of chromic anhydride. The mixture was heated for 2 hours at 90-100°. We obtained 1.5 g (46%) of terephthalic acid, which indicated the presence of 57% para-isomer.

6. Reduction of chloromethyltoluene. To the organomagnesium compound prepared from 38.2 g (0.27 mole) of chloromethyltoluene and 18 g (0.67 g-atom) of magnesium was slowly added 40 g (1.2 moles) of methyl alcohol and then 300 ml of 10% hydrochloric acid. We obtained 21.2 g (74%) of a fraction with b. p. 136-144°. The frequencies of the lines in the Raman spectrum of the fraction were as follows (in cm^{-1}):

185(4), 257 (3), 315 (6), 350 (vw),* 387 (2), 434 (3), 460 (7), 484 (0), 510 (3), 584(7), 644(6), 697(1), 701 (1), 736 (10), 785(1), 813(4), 830(9), 863(1), 936(0), 988 (2), 1002(2), 1034(0), 1055 (8), 1158(2, d), 1184 (2), 1207 (9), 1225 (7), 1287 (1, d), 1312 (2), 1382(7), 1453 (3, d), 1581 (2), 1608 (2), 1619 (7).

B. Syntheses based on ethylbenzene. 1. Chloromethylethylbenzene. The reaction was carried out by the method used by us for the chloromethylation of toluene. For the reaction we used: 84 g (0.79 mole) of ethylbenzene, 111 g (1.28 moles) of 35% formalin, and 25 g of zinc chloride. We obtained 39 g (32%) of chloromethylethylbenzene.

2. Di(ethylbenzyl)diethylsilane. To the organomagnesium compound prepared from 19.2 g (0.8 g-atom) of magnesium and 103.7 g (0.67 mole) of chloromethylethylbenzene was added 52.3 g (0.33 mole) of diethyldichlorosilane. The mixture was heated for 8 hours. We obtained 18.4 g (21.7%). On fractionation ethylbenzyldiethylsilanol also was isolated in the amount of 27 g (41.7%).

3. Oxidation of ethylbenzyldiethylsilanol. To a mixture of 5.50 g (0.025 mole) of ethylbenzyldiethylsilanol, 25 ml of 98% sulfuric acid, 85 ml of glacial acetic acid, and 85 ml of water was slowly added 100 g of chromic anhydride. The mixture was heated for 2 hours at 90-100°. We obtained 1.75 g (42.5%) of terephthalic acid, which indicated the presence of 52% para-isomer.

4. Oxidation of di(ethylbenzyl)diethylsilane. To a mixture of 4.25 g (0.013 mole) of di(ethylbenzyl)-diethylsilane, 34 ml of 98% sulfuric acid, 100 ml of glacial acetic acid, and 100 ml of water was slowly added 120 g of chromic anhydride. The mixture was heated for 2 hours at 90-100°. We obtained 3.3 g (75.5%) of terephthalic acid, which indicated the presence of 93% para-isomer.

5. Reduction of chloromethylethylbenzene. To the organomagnesium compound prepared from 59 g (0.39 mole) of chloromethylethylbenzene and 18 g (0.67 g-atom) of magnesium was added 40 g (1.2 moles) of methyl alcohol and then 300 ml of 10% hydrochloric acid. We obtained 35 g (77%) of a fraction with b. p. 156-161°. The frequencies of the lines in the Raman spectrum were as follows (in cm^{-1}):

221 (5, w), 315 (2), 363 (3), 397 (bg), 461 (4), 496 (3), 552 (3), 585 (5), 647 (8), 716 (6), 725 (6), 804 (10), 823 (10, sh), 967 (4), 1001 (5), 1034 (4), 1062 (8), 1158 (4), 1177 (5), 1201 (10, sh), 1221 (6), 1245 (1), 1286 (2), 1325 (3), 1379 (8), 1452 (5, w), 1581 (3), 1615 (936).

* w = wide, vw = very wide, d = doublet, bg = background, sh = sharp.

C. Syntheses based on isopropylbenzene.   1.   Chloromethylisopropylbenzene.   The reaction was carried out by the method used for the chloromethylation of toluene.   We used 100 g (0.83 mole) of isopropylbenzene, 113 g (1.32 mole) of 35% formalin, and 30 g of zinc chloride.   We obtained 35 g (26%) of chloromethylisopropylbenzene.

2.   Isopropylbenzyltrimethylsilane.   To the organomagnesium compound prepared from 7 g (0.29 g-atom) of magnesium and 33.7 g (0.2 mole) of chloromethylisopropylbenzene was added 21.8 g (0.2 mole) of trimethylchlorosilane.   The mixture was heated for 10 hours.   We obtained 21.4 g (52%).

3.   Di(isopropylbenzyl)dimethylsilane.   To the organomagnesium compound prepared from 9 g (0.37 g-atom) of magnesium and 60 g (0.36 mole) of chloromethylisopropylbenzene was added 18 g (0.12 mole) of dimethyldichlorosilane.   The mixture was heated for 14 hours.   We obtained 27 g (60.8%).

4.   Di(isopropylbenzyl)diethylsilane.   To the organomagnesium compound prepared from 12 g (0.5 g-atom) of magnesium and 80 g (0.48 mole) of chloromethylisopropylbenzene was added 30 g (0.19 mole) of diethyldichlorosilane.   The mixture was heated for 14 hours.   We obtained 40 g (48%).

5.   Oxidation of isopropylbenzyltrimethylsilane.   To a mixture of 4.13 g (0.02 mole) of compound, 30 ml of 98% sulfuric acid, 100 ml of glacial acetic acid, and 100 ml of water was slowly added 120 g of chromic anhydride.   The mixture was heated for 2 hours at 90-100°.   We obtained 2.32 g (70%) of terephthalic acid, which indicated the presence of 85.5% of para-isomer.

6.   Oxidation of di(isopropylbenzyl)dimethylsilane.   To a mixture of 4.036 g (0.012 mole) of compound, 30 ml of 98% sulfuric acid, 100 ml of glacial acetic acid, and 100 ml of water was slowly added 110 g of chromic anhydride.   The mixture was heated for 2 hours at 90-100°.   We obtained 2.99 g (73%) of terephthalic acid, which indicated the presence of 90% para-isomer.

7.   Oxidation of di(isopropylbenzyl)diethylsilane.   To a mixture of 4.04 g (0.0114 mole) of compound, 32 ml of 98% sulfuric acid, 100 ml of glacial acetic acid, and 100 ml of water was slowly added 110 g of chromic anhydride.   The mixture was heated for 2 hours at 90-100°.   We obtained 2.92 g (79%) of terephthalic acid, which indicated the presence of 97.3% of para-isomer.

8.   Reduction of chloromethylisopropylbenzene.   To the organomagnesium compound prepared from 45 g (0.27 mole) of chloromethylisopropylbenzene and 18 g (0.67 g-atom) of magnesium was added 40 g (1.2 moles) of methyl alcohol and then 300 ml of 10% hydrochloric acid.   We obtained 25.8 g (72%) of a fraction with b. p. 76-80° (22 mm).   The frequencies of the lines in the Raman spectrum were as follows (in cm^{-1}):

220 (5),   304 (3),   385 (2),   440 (4),   590 (1),   640 (6),   718 (4),   806 (10),   818 (6),   891 (2),   956 (1), 1000 (1),   1040 (3),   1060 (4),   1108 (2),   1159 (1),   1190 (4),   1210 (9),   1228 (1),   1282 (1),   1301 (3),   1379 (5), 1444 (3),   1460 (4),   1575 (1),   1614 (8).

SUMMARY

1.   Toluene and ethyl- and isopropylbenzene were chloromethylated.   The formation of para- and ortho-isomers on chloromethylation was demonstrated.

2.   From the chloromethylated alkylbenzenes were obtained a number of silicohydrocarbons with alkylbenzyl radicals on the silicon atom.   It was shown that as the size of the alkyl radical in the alkylbenzyldiethylsilanes increased, the para-isomer content rose.

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DIPOLE MOMENTS AND ACTIVITY IN THE TELOMERIZATION OF SOME ALLYL CHLORIDES WITH DIENE HYDROCARBONS*

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In a series of investigations on the telomerization of diene hydrocarbons with alkyl and alkenyl chlorides it has been shown that the average value of x in the general formula of the telomers $R-(C_nH_{2n-2})_x-Cl$ depends primarily on the nature of the radical in the halogen derivative. Primary and secondary alkyl chlorides and primary alkenyl chlorides, and also secondary and tertiary alkenyl chlorides that are capable of yielding primary alkenyl chlorides as a result of allyl rearrangement, form a mixture of compounds containing a large amount of products of extensive telomerization, even when the starting diene is used at the rate of 25-30%. At the same time, tertiary alkyl chlorides and secondary alkenyl chlorides that are incapable of rearrangement to primary compounds form considerable amounts of compounds with the formula $R-C_nH_{2n-2}-Cl$ when 80-100% diene is used [1-5].

At first the greater or lesser extent of telomerization was connected with the relative activity of the starting halogen derivative and the initial telomerization products [1]. However, it was later concluded that the nature of this phenomenon is more complex and is dependent on peculiarities of the reaction mechanism [2, 5].

It was further established that alkenyl chlorides capable of allyl rearrangement yield telomers of approximately the same composition regardless of which allyl isomers are used in the reaction; in this connection, in the case of primary — secondary and primary — tertiary allyl isomers the reaction goes predominantly as if we had to do only with the primary halogen derivative.

To clarify the reason for these and some other rules in the telomerization of diene hydrocarbons with halogen derivatives and to show the connection between their structure and reactivity it was necessary to have as much detailed data as possible on the physical properties of the starting halogen derivatives and the telomers obtained from them.

For this purpose, we investigated the dipole moments of a number of hydrochlorides of diene hydrocarbons and the initial products of their telomerization with the same and with other dienes. The diene hydrochlorides were pure materials. Crotyl chloride and 2-chloropentene-3 were preferentially of the trans-configuration. The telomers in the majority of cases were mixtures with a considerable predominance of the isomers listed in Tables 1 and 2. The latter circumstance necessitated caution in the use of the data on the telomers.

Comparison of the dipole moments of the diene hydrochlorides investigated with that of allyl chloride led us to the following conclusions.

1. Allylic halogen derivatives have somewhat smaller dipole moments than the corresponding saturated analogs [6].

2. The dipole moments of allylic halogen derivatives increase with an increase in the number of methyl groups at the double bond.

3. The methyl groups on the carbon attached to the chlorine have a similar but somewhat weaker effect on the magnitude of the dipole moment.

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* Investigation in the field of conjugated systems. CVI. Diene compounds. LXXVII.

4. The appearance of a second chlorine atom at the double bond leads to a small increase in the moment.

The second and third characteristics mentioned above lead to the conclusion that the 1,4-adducts of hydrogen chloride with dienes have larger moments than 1,2-adducts.

TABLE 1
Constants of Chlorides

Compound	Boiling point (Pressure in mm)		d_4^{20}	n_D^{20}	MR	
					found	calc.
$CH_2=CH-CH_2-Cl$	45°	(760)	0.9379	1.4154	20.45	20.45
$CH_2=CH-CH-Cl$ $\vert$ CH_3	63.5—64	(760)	0.8978	1.4149	25.25	25.07
$CH_2=CH-\overset{CH_3}{\underset{CH_3}{\overset{\vert}{\underset{\vert}{C}}}}-Cl$	29—30	(120)	0.8837	1.4190	29.88	29.69
$CH_3-CH=CH-CH_2-Cl$	84—84.5	(760)	0.9282	1.4350	25.46	25.07
$CH_2-CH=CH-CH-Cl$ $\vert$ CH_3	45—46	(120)	0.9003	1.4326	30.16	29.69
$CH_3-C=CH-CH_2-Cl$ $\vert$ CH_3	39—40	(50)	0.9282	1.4507	30.31	29.69
$CH_3-C=CH-CH_2-Cl$ $\vert$ Cl	53—54	(50)	1.1494	1.4730	30.51	29.94
$CH_2=CH-CH-Cl$ $\vert$ $CH_2-CH_2-CH=CH-CH_3$	54—56	(10)	0.9117	1.4580	43.28	43.08
$CH_2=CH-CH-Cl$ $\vert$ $CH_2-CH-CH=CH-CH_3$ $\vert$ CH_3	58—58.5	(10)	0.9032	1.4570	47.84	47.70
$CH_2-CHCl-CH=CH$ $\vert$ $CH_2-CH-CH=CH-CH_3$ $\vert$ CH_3	78.5—79	(10)	0.8915	1.4622	53.27	52.31
$CH_3-CH=CH-CH_2-CH_2-CH=CH-CH_2-Cl$	66—68	(10)	0.9223	1.4678	43.57	43.08
$CH_3-CH=CH-CH-CH_2-CH=CH-CH_2-Cl$ $\vert$ CH_3	71—72	(10)	0.9252	1.4691	47.76	47.70
$CH_3-CH=CH-CH-CH_2-C=CH-CH_2-Cl$ $\vert$ CH_3 $\vert$ CH_3	83.5—84	(510)	0.9161	1.4740	52.98	52.31
$CH_3-CH=CH-CH-CH_2-C=CH-CH_2-Cl$ $\vert$ CH_3 $\vert$ Cl	92—92.5	(10)	1.0366	1.4840	53.30	52.56

In the series of telomers that we investigated we observed consistently that the magnitude of the moment affects only substitution in the system $C=C-C-Cl$. Therefore, the telomers have moments very close to those of the hydrochlorides having the same structure in the chlorine-containing group.

There is some parallelism between the magnitude of the dipole moment and the activity of the chlorides in reactions of the SN_1 type. However, the dipole moments are not here a sensitive criterion of activity.

Thus, in going from allyl chloride to crotyl chloride and further to prenyl chloride the dipole moments change by 0.20-0.16 D, and the hydrolysis rate constants of these chlorides for a monomolecular mechanism change by 1,000 and 10,000 times, respectively. Prenyl chloride has a moment greater by 0.07 D than its allyl isomer, dimethylvinylchloromethane; however, the latter has a 5 times greater hydrolysis rate constant [7]. Thus, the relationship existing here is not simple.

There also is no simple relationship between the magnitude of the dipole moment and the tendency of the chlorides to a greater or lesser degree of telomerization. Crotyl chloride has a smaller, and prenyl chloride a greater dipole moment than 2-chloropentene-3; however, the first two compounds behave alike in the telomerization reaction, but the last-named breaks off the reaction in the early stages.

Comparison of the moments of the hydrochlorides and those of the telomers obtained from them does not reveal any rule. The dipole moment of the products of telomerization of 2-chloropentene-3 with divinyl is less than, and that of its telomerization products with isoprene is approximately equal to the moment of the starting chloride. Comparison of the moments of crotyl chloride and of its telomers with divinyl leads to a similar conclusion.

However, the further behavior of the initial telomers in these two cases is different.

TABLE 2
Dipole Moments of Chlorides and Starting Data for Calculation

Compound	ε_0	α	v_0	$-\beta$	P_∞	μ (in D)
$CH_2=CH-CH_2-Cl$	2.282	4.44	1.1371	0.071	87.64	1.79
$CH_2=CH-CH-Cl$ $\quad\quad\quad\;CH_3$	2.282	4.60	1.1371	0.024	107.67	1.99
CH_3 $CH_3=CH-C-Cl$ $\quad\quad\quad\;CH_3$	2.284	4.38	1.1373	0.006	120.62	2.09
$CH_3-CH=CH-CH_2-Cl$	2.282	5.23	1.1370	0.051	117.54	2.10
$CH_3-CH=CH-CH-Cl$ $\quad\quad\quad\quad\quad\;CH_3$	2.282	4.83	1.1371	0.026	128.76	2.17
$CH_3-C=CH-CH_2-Cl$ $\quad\;CH_3$	2.284	5.20	1.1372	0.058	134.92	2.24
$CH_2-C=CH-CH_2-Cl$ $\quad\;Cl$	2.283	4.06	1.1370	0.270	126.83	2.15
$CH_2=CH-CH-Cl$ $\quad\quad\quad\;CH_3-CH_2-CH=CH-CH_3$	2.282	2.94	1.1371	0.038	126.69	2.00
$CH_2=CH-CH-Cl$ $\quad\quad\quad\;CH_2-CH-CH=CH-CH_3$ $\quad\quad\quad\quad\quad\;CH_3$	2.283	2.68	1.1370	0.030	131.68	2.00
$CH_3-CHCl-CH=CH$ $\quad\quad\quad\;CH_3-CH-CH=CH-CH_3$ $\quad\quad\quad\quad\quad\;CH_3$	2.283	3.00	1.1370	0.017	154.27	2.20
$CH_2-CH=CH-CH_2-CH_2-CH=CH-CH_2-Cl$	2.282	3.20	1.1371	0.052	133.09	2.08
$CH_3-CH=CH-CH-CH_2-CH=CH-CH_2-Cl$ $\quad\quad\quad\quad\;CH_3$	2.283	2.88	1.1370	0.056	136.34	2.06
$CH_2-CH=CH-CH-CH_2-C=CH-CH_2-Cl$ $\quad\quad\quad\quad\;CH_3\quad\quad\;CH_3$	2.284	2.98	1.1373	0.047	152.17	2.18
$CH_3-CH=CH-CH-CH_2-C=CH-CH_2-Cl$ $\quad\quad\quad\quad\;CH_3\quad\quad\;Cl$	2.283	2.86	1.1370	0.178	158.17	2.24

In all the reactions investigated the telomerization proceeds at the expense of that ion that corresponds to the greatest dipole moment.

Thus, as a result of this investigation, it was established that the characteristics of the behavior of the halogen derivatives in telomerization reactions with dienes is not determined only by the magnitudes of their dipole moments and the moments of the telomers.

EXPERIMENTAL

Methods of preparation of all the compounds investigated have been described in previous articles [1-5]. The constants used for determining the samples of halogen derivatives are given in Table 1.

The dipole moments were determined by the method of dilute solutions of Debye [8]. The dielectric permeability was measured with a MLE-1 bridge especially fitted for this purpose. The error in the measurements of dipole moments did not exceed 0.02 D. The measurements were made in benzene solutions at 20° with concentrations of the order of 1.0, 1.5, 2.0, 4.0, and 5.0%. The molecular polarization and the dipole moments were calculated by the usual formulas [8]. The atomic polarization was not considered. The results of the measurements and calculations are given in Table 2.

SUMMARY

1. The dipole moments of some hydrochlorides of diene hydrocarbons and the initial products of their telomerization with the same or other dienes have been determined.

2. Some regularities in the dipole moments of these compounds have been considered and it has been shown that there is no direct connection between the activity characteristics and the dipole moments.

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INVESTIGATIONS IN THE FIELD OF CONJUGATED SYSTEMS

CVII.* THE ORDER OF ADDITION OF IODINE CHLORIDE TO VINYLACETYLENE HYDROCARBONS

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The order of addition of halogens to vinylacetylene hydrocarbons depends on their structure and the nature of the halogen. While iodine, independent of the structure of the hydrocarbon, forms 1,3-diene diiodides, bromine in the case of the vinylalkylacetylenes adds at the double bond and in the case of unsubstituted vinylacetylene and alkenylacetylenes adds in the 1,4-positions and at the triple bond [1-4].

Continuing our study of the rules for the reactions of vinylacetylene hydrocarbons with halogens, we have investigated their reaction with iodine chloride.

As a result of the addition of iodine chloride to vinylacetylene we obtained two fractions of adduct with the composition C_4H_4ClI, which differed in boiling point and other properties.

The lower boiling product was more stable toward alcoholic alkali. In its infrared spectrum there were intense frequencies characteristic of a conjugated system of double bonds (1543 and 1614 cm^{-1}), a vinyl group (949 and 970 cm^{-1}), a terminal methylene group $CH_2 =$ (about 6100 cm^{-1} — overtone), and also a terminal acetylene group (2133 and 3294 cm^{-1}). These data indicated that the lower boiling product was the compound (I) with an admixture of the acetylenic adduct (II).

The higher boiling product, which was predominantly formed, had a chlorine atom that was very unstable toward alcoholic alkali. In its infrared spectrum there was an intense frequency of an allene group (1948 cm^{-1}). The frequencies for the 1,3-diene system, terminal acetylene and methylene groups were so weak that the corresponding compounds could be considered to be present only in very small traces. These data indicated that the higher boiling product was predominantly compound (III).

$$CHI =CCl-CH=CH_2, \quad CH \equiv C-CHCl-CH_2I, \quad CHI =C=CH-CH_2Cl$$
$$(I) \qquad\qquad (II) \qquad\qquad (III)$$
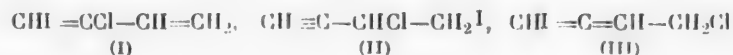
Thus, it was established that vinylacetylene adds iodine chloride predominantly in the 1,4-positions and at the acetylenic bond, i.e., in the same order as bromine [1]. It must be noted that to obtain any significant yields of monochloroiodo adducts we had to use a large excess of vinylacetylene.

The addition of iodine chloride to propenylacetylene took place predominantly at the acetylenic bond. By fractional distillation of the reaction product we also obtained here two fractions of chloroiodo adducts of the composition C_5H_6ClI; the first, predominant fraction, judged by its spectrum (presence of intense frequencies for the group: $-CH=CH-CCl=CH-$, 845, 954, 1590, 1641 cm^{-1}) and its relative stability toward the action of alcoholic alkali (in the cold), was the 1,3-diene chloroiodide (IV), and the second fraction contained the

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* Enyne compounds. XXX.

allene adduct (V) along with the 1,3-diene adduct. In this case, the acetylenic adduct (VI) was practically absent from the reaction products (the intensity of the frequency 3295 cm^{-1} was insignificant).

$$CH_3-CH=CH-CCl=CHI, \quad CH_3-CHCl-CH=C=CHI,$$
$$(IV) \qquad\qquad\qquad (V)$$
$$CH_3-CHI-CHCl-C\equiv CH$$
$$(VI)$$
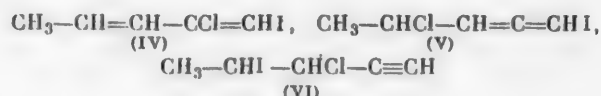
The addition of iodine chloride to vinylalkylacetylenes (penten-1-yne-3 and hexen-1-yne-3) took place, like the addition of bromine [2], practically exclusively at the ethylenic bond with the formation of compounds of the type of (VII). In the infrared spectrum of the adducts there were intense frequencies only for the acetylene group (2240-2250 cm^{-1}). The frequencies of the allene group (VIII) and the 1,3-diene group (IX) were practically absent.

$$R-C\equiv C-CHCl-CH_2I, \quad R-CCl=C=CH-CH_2I, \quad R-CI=CCl-CH=CH_2$$
$$(VII) \qquad\qquad\qquad (VIII) \qquad\qquad\qquad (IX)$$
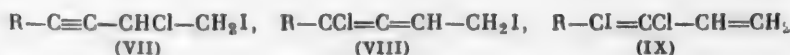
In conformance with their structure, the chloroiodo adducts of the vinylalkylacetylenes readily split out hydrogen iodide in the presence of alcoholic alkali with the formation of chlorine-substituted vinylalkylacetylenes (X) not previously described in the literature.

$$R-C\equiv C-CCl=CH_2$$
$$(X)$$
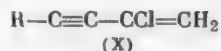
These compounds were colorless liquids, with a characteristic odor, strongly refracting light and polymerizing quickly on standing. In the infrared spectra of these compounds there was a frequency of 1603 cm^{-1} corresponding to a double bond, and two frequencies of about 2200 and 2250 cm^{-1} corresponding to a triple bond. The double bond frequencies were greatly diminished in comparison with the usual values for ethylenic and even 1,3-diene hydrocarbons. A similar phenomenon had been noted previously in the spectra of vinylacetylenic hydrocarbons [5] and esters [6]. The characteristic intense frequency 885 cm^{-1} belongs to the CH$_2$=group.

Formation of chlorovinylacetylenes of structure (X) from the chloroiodo adducts of vinylalkylacetylenes indicates that, as indicated in the case of Formula (VII), iodine chloride adds at the site of the ethylenic bond. If the order of addition were different, it would be impossible to obtain a chlorovinylacetylene with a terminal methylene group by dehydrohalogenation of the compound.

The order of addition of iodine chloride to isopropenylacetylene proved to be similar to the addition to vinylalkylacetylenes. In the infrared spectrum of the adduct the intense frequencies of the terminal acetylene group of the starting hydrocarbon (2120 and 3285 cm^{-1}) and the considerably more weakened frequencies of the isopropenyl group (885, 1593, 3057, and about 6100 – overtone – cm^{-1}) were preserved. The frequencies of the allene group of compound (XIII) were not observed. These data indicate that the adduct consisted chiefly of the acetylenic compound (XI) with an admixture of 1,3-diene (XII).

The 1,3-diene adduct might have a different structure depending on its derivation. Direct addition of iodine chloride at the acetylenic bond should yield a product with the formula (XII). Isomerization of the adduct (XI) should lead to the formation of a compound with the halogen atoms in a different position (XIV).

$$CH_2I-CCl-C\equiv CH, \quad CH_2=C-CCl=CHI, \quad CH_2Cl-C=C=CHI,$$
$$\qquad | \qquad\qquad\qquad | \qquad\qquad\qquad | $$
$$\qquad CH_3 \qquad\qquad\qquad CH_3 \qquad\qquad\qquad CH_3$$
$$\qquad (XI) \qquad\qquad\qquad (XII) \qquad\qquad\qquad (XIII)$$
$$CH_2=C-CI=CHCl, \quad CH_2=C-C\equiv CI$$
$$\qquad | \qquad\qquad\qquad | $$
$$\qquad CH_3 \qquad\qquad\qquad CH_3$$
$$\qquad (XIV) \qquad\qquad\qquad (XV)$$
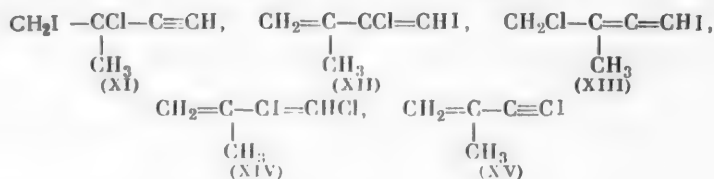
The question of the structure of the main part of the 1,3-diene adduct was resolved on the basis of an analysis of the infrared spectrum of a mixture of compounds produced by the action of alcoholic alkali on the initial adduct. This mixture boiled over a wide temperature range, but so high that it could not contain vinyl-acetylene chlorides like those obtained from the vinylalkylacetylenes. In the infrared spectrum of the dehalo-genation products the frequencies of the terminal acetylene group of the starting compound (2120 and 3285 cm^{-1})

were not present, while an intense double bond frequency (1618 cm^{-1}) appeared, and particularly important, an intense frequency at 2164 cm^{-1} which could be ascribed only to a terminal acetylene group substituted with halogen, i.e., to compound (XV), the formation of which is only possible from adduct (XII).
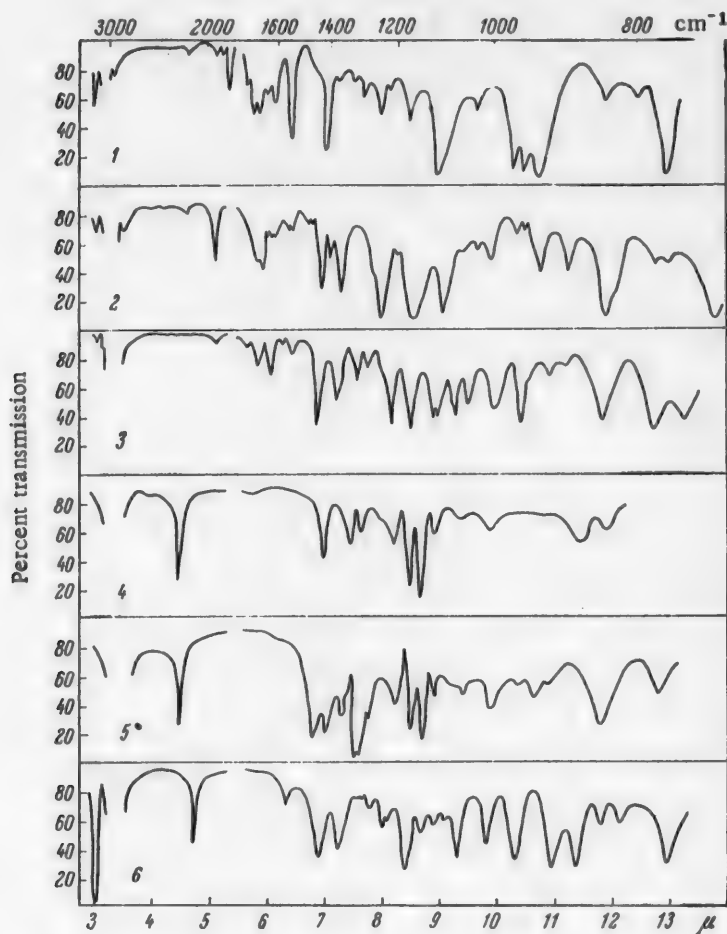
Fig. 1. Infrared absorption spectra. 1) Chloroiodo adduct of vinyl-acetylene, fraction 39-40° (5 mm); 2) chloroiodo adduct of vinyl-acetylene, fraction 63-64° (5 mm); 3) chloroiodo adduct of propenyl-acetylene, fraction 58.5-59° (5 mm); 4) chloroiodo adduct of vinyl-methylacetylene, fraction 71-73° (5 mm); 5) chloroiodo adduct of vinylethylacetylene, fraction 78-79° (5 mm); 6) chloroiodo adduct of isopropenylacetylene, fraction 46-46.5° (5 mm).

Consequently, the 1,3-diene adduct, at least in the main, was produced as a result of direct addition of the iodine chloride at the triple bond (or as a result of isomerization of the allene adduct (XIII), which, however, was not detected) and was not a product of isomerization of the acetylenic adduct (XI).

Thus, as a result of this investigation it has been established that addition of iodine chloride to vinyl-acetylene hydrocarbons takes place qualitatively in the same order as the addition of bromine to these hydro-carbons, and that it differs from the order of addition of iodine.

If we start with the earlier hypothesis that the difference in the order of addition of bromine and iodine is connected with differences in the addition mechanism, then we should consider that the addition of iodine chloride has an ionic mechanism. Such a mechanism for iodine chloride is still more likely than for bromine,

inasmuch as iodine chloride is a polar compound. The structure of the compounds obtained indicates that attack anywhere starts with the iodine atom.

Small differences in the order of addition of bromine and iodine chloride may be connected with two reasons. First, with the polarity of iodine chloride, as a result of which the molecule of vinylacetylene hydrocarbon is more polarized at the moment of reaction. This possibly explains the larger amount of chloroiodo addition at the acetylenic bond in the case of propenylacetylene than in the bromination of this hydrocarbon. The second reason is negligible differences in the reaction conditions. It has been shown, for example, that in the case of vinylacetylene a change in temperature greatly affects the ratio of the products of addition in the 1,4-positions and at the acetylenic bond [7].
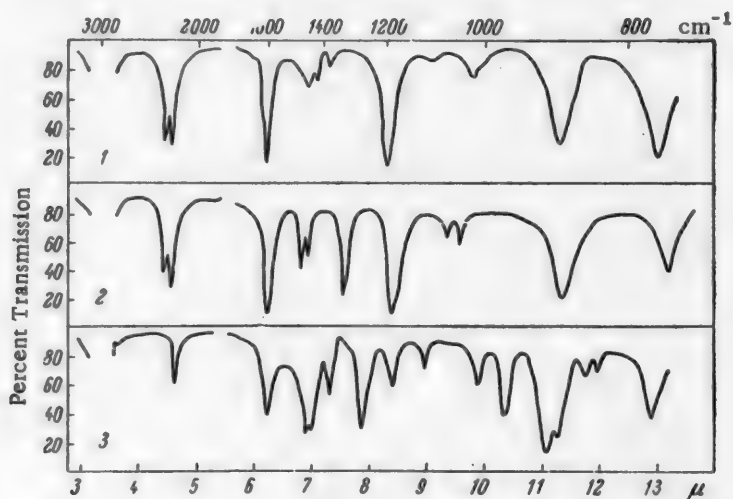
Fig. 2. Infrared absorption spectra. 1) Chlorovinylmethylacetylene; 2) chlorovinylethylacetylene; 3) dehydrohalogenation product of the chloroiodo adduct of isopropenylacetylene, fraction 90-100° (100 mm).

Differences in the order of addition of iodine chloride to homologs of vinylacetylene can be explained by electron migrations in the molecules of these hydrocarbons in accordance with the formulas given below. These shifts are considerably reinforced by the action of the attacking molecule.
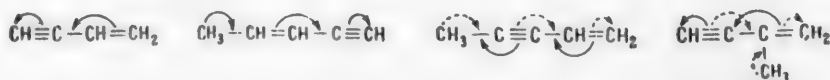
Such a shift in electron density has been suggested previously on the basis of chemical, and in part spectral data [2, 5]. Now the reality of this phenomenon has been confirmed by measurements of the dipole moments of the vinylacetylenes [8]. It has been shown that the dipole moments of vinylalkylacetylenes and isopropenylacetylene are lower and the dipole moment of propenylacetylene is higher in comparison with the moment of the unsubstituted vinylacetylene. Thus, the explanation of rules for the order of addition of halogens to vinylacetylene hydrocarbons of different structures has received direct physical confirmation.

The products of the addition of two molecules of iodine chloride to vinylacetylenes which are formed in all cases have not been more closely investigated.

EXPERIMENTAL

Addition of iodine chloride to vinylacetylene. To a solution of vinylacetylene in chloroform (200 ml) at minus 5-10° was added dropwise, with mechanical stirring, a solution of iodine chloride in the same solvent (100 ml).

When the reaction ended, the mixture was distilled in vacuo. In this way we obtained from 43 g (5.5 times excess) of vinylacetylene and 24.4 g of iodine chloride a 10.5 g fraction with b. p. up to 100° (5 mm) and 15.5 g of residue; in another experiment we obtained from 54.6 g of vinylacetylene (7 times excess) and the same amount of iodine chloride a 14.9 g fraction up to 100° (5 mm) and 14.5 g of residue.

When the products from the two experiments with b. p. up to 100° (5 mm) were distilled, the following fractions were obtained: 1st, up to 39°, 0.5 g; 2nd, 39-40°, 3.1 g (2-chloro-1-iodobutadiene-1,3 with admixed 2-chloro-1-iodobutyne-3); 3rd, 40-63°, 2.0 g; 4th, 63-64°, 8.5 g (4-chloro-1-iodobutadiene-1,2); 5th, 64-70°, 1.5 g; 6th, residue, 6.2 g.

Investigation of 39-40° (5 mm) fraction: d_4^{20} 1.8920, n_D^{20} 1.5986, MR 38.70; Calc. 37.40.

Found %: Cl + I 74.35, 74.84. C_4H_4ClI. Calculated %: Cl + I 75.72.

IR spectrum: 769 v.s., 799 w., 836 w., 926 v.s., 949 s., 970 s., 1031 m., 1111 v.s., 1171 m., 1218 w., 1245 m., 1293 w., 1321 w., 1369 w., 1410 s., 1543 s., 1614 m., 1686 m., 1711 m., 1750 w., 1854 m., 1894 w., 1930 w., 2133 w., 2974 w., 3018 w., 3064 s., 3090 s., 3294 m. cm^{-1}.

When a sample of the material (about 0.5 g) stood for 2 hours with 5% alcoholic solution of KOH (2 equiv.), 28.6% of the chlorine and 32.9% of the iodine in the sample went into solution.

Investigation of 63-64° (5 mm) fraction: d_4^{20} 1.9626, n_D^{20} 1.6280, MR 38.77; Calc. 37.40.

Found %: Cl + I 75.27. C_4H_4ClI. Calculated %: Cl + I 75.72.

IR spectrum: 722 v.s., 769 w., 782 w., 837 v.s., 887 m., 927 m., 949 w., 965 w., 1010 m., 1031 m., 1057 m., 1100 s., 1167 v.s., 1209 w., 1250 s., 1370 s., 1401 m., 1435 s., (1480 w., 1550 w., 1622 w., 1630 w., 1652 w.),* 1686 m., 1701 m., 1836 w., 1948 s., 2240 w., 2859 w., 2952 m., 3035 s., 3292 w. cm^{-1}.

When a sample of the material stood with an alcoholic solution of KOH under the conditions mentioned above, 79.8% of the chlorine and 25.55 of the iodine in the sample went into solution.

Addition of iodine chloride to propenylacetylene. To a solution of 13.2 g (double excess) of propenyl-acetylene (a mixture of approximately equal parts of cis- and trans-forms) in 150 ml of chloroform was added 16.2 g of iodine chloride in 50 ml of chloroform under the conditions indicated above. The unreacted hydrocarbon and part of the chloroform were distilled off in vacuo (the receiver was cooled with solid carbon dioxide) and a solution of 8 g of iodine chloride in chloroform was added to them under the same conditions.

As a result of the initial distillation of the two reaction products, we obtained 15.7 g of products with b. p. up to 100° (4 mm) and 12 g of residue. Upon distillation of the lower boiling products we obtained the following fractions: 1st, up to 58°, 0.5 g; 2nd, 58.5-59°, 10.0 g (2-chloro-1-iodopentadiene-1,3); 3rd, 59-75°, 3.2 g (n_D^{20} 1.6000); 4th, residue, 1.5 g.

Investigation of 58.5-59° (4 mm) fraction: d_4^{20} 1.7504, n_D^{20} 1.5900, MR 44.05; Calc. 42.02.

Found %: Cl + I 70.80, 71.00. C_5H_6ClI. Calculated %: Cl + I 71.07.

IR spectrum: 710 s., 754 s., 785 s., 845 s., 890 v. w., 917 w., 948 w., 954 s., 1000 s., 1050 m., 1078 s., 1116 s., 1171 s., 1219 s., 1282 w., 1316 w., 1385 m., 1444 s., 1550 w., 1590 w., 1641 m., 1705 m., 1756 w., 1948 w., 2866 w., 2909 m., 2974 s., 2988 s., 3069 s., 3094 w., 3293 v. w. cm^{-1}.

When a sample of the material stood with a 4-times excess of 10% solution of KOH in alcohol, about 50% of the halogens in the sample were hydrolyzed.

The infrared spectrum of the 59-75° (4 mm) fraction differed only in the greater intensity of the 1950 cm^{-1} frequency and the weakening of the 954 cm^{-1} frequency.

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* These weak bands apparently consisted of two frequencies each.

Addition of iodine chloride to vinylmethylacetylene. Under the usual conditions we obtained from 33 g of hydrocarbon and 40.5 g of iodine chloride 22.2 g of a product that distilled up to 100° (5 mm) and 25.5 g of residue. When the first product was distilled, the following fractions were obtained: 1st, up to 71°, 2 g; 2nd, 71-73°, 14.7 g (2-chloro-1-iodopentyne-3); 3rd, 73-80°, 2.5 g; 4th, residue, 3.0 g.

Investigation of 71-73° (5 mm) fraction: d^{20}_4 1.7910, n^{20}D 1.5692, MR 41.80; Calc. 40.96.

Found %: Cl + I 70.39, 70.50. C_5H_6ClI. Calculated %: Cl + I 71.07.

IR spectrum: 840 m., 860 m., 1008 w., 1071 v.w., 1123 m., 1158 s., 1182 s., 1220 s., 1311 m., 1338 m., 1428 s., **2249** s., 2843 m., 2911 s., 2955 s., 3025 m. cm^{-1}.

A solution of 14 g of the 71-73° (5 mm) fraction and 5 g of KOH in 35 ml of alcohol was allowed to stand for a day at room temperature and then the reaction products were distilled off with steam and separated from the distillate by salting out with a saturated solution of calcium chloride. As a result, we obtained 3.5 g of an oil, of which 2/3 distilled over within a 1° range.

2-Chloropenten-1-yne-3. B. p. 52-53° (100 mm), d^{20}_4 0.9911, n^{20}D 1.4842, MR 29.03; Calc. 27.69.

Found %: C 61.27, 60.98; H 5.38, 5.31; Cl 33.78, 33.95. C_5H_5Cl. Calculated %: C 59.72; H 5.01; Cl 35.26.

IR spectrum: 769 v.s., 885 v. s., 1048 m., 1092 v.w., 1200 v. s., 1368 w., 1404 w., 1425 w., **1605** s., 1667 v. w., **2217** s., 2261 s. cm^{-1}.

Addition of iodine chloride to vinylethylacetylene. Under the usual conditions, we obtained from 46 g (double excess) of hydrocarbon and 46.2 g of iodine chloride 28 g of a product that distilled up to 100° (5 mm) and 20.5 g of residue. By repeated distillation of the first product we obtained the following fractions: 1st, up to 78°, 2.5 g; 2nd, 78-79°, 16 g (2-chloro-1-iodohexyne-3); 3rd, 79-85°, 2.1 g; 4th, residue, 5 g.

Investigation of 78-79° (5 mm) fraction: d^{20}_4 1.6967, n^{20}D 1.5000, MR 46.22; Calc. 45.57.

Found %: Cl + I 66.88, 66.85. C_6H_8ClI. Calculated %: Cl + I 66.96.

IR spectrum: 780 s., 846 v.s., 922 m., 944 m., 959 m., 1014 m., 1064 m., 1122 m., 1150 s., 1178 s., 1216 s., 1303 m., 1323 s., 1332 s., 1380 m., 1420 s., 1458 s., **2241** s., 2844 w., 2873 m., 2914 s., 2931 s., 2970 s., 3024 w. cm^{-1}.

After a solution of 15.5 g of the 78-79° (5 mm) fraction and 5.5 g of KOH in 35 ml of alcohol had stood for a day, we obtained by the above-described method 2 g of chlorovinylethylacetylene (2-chlorohexen-1-yne-3) with the following constants.

B. p. 68-70° (100 mm), d^{20}_4 0.9693, n^{20}D 1.4830, MR 33.76; Calc. 32.31.

Found %: C 63.17, 63.39; H 6.38, 6.32; Cl 30.38, 30.29. C_6H_7Cl. Calculated %: C 62.89; H 6.16; Cl 30.95.

IR spectrum: 754 m., **884** v.s., 1046 m., 1072 m., 1195 v.s., 1322 s., 1444 m., 1469 s., **1603** s., **2220** s., 2247 s., 2880 m., 2914 m., 2933 m., 2976 s., 3059 w. cm^{-1}. Intense overtone in the 6100 cm^{-1} region.

Addition of iodine chloride to isopropenylacetylene. From 26 g of hydrocarbon (double excess) and 32 g of iodine chloride we obtained 16.5 g of a product that distilled up to 80° (5 mm) and 20.8 g of residue.

Distillation of the first product at 5 mm gave the following fractions: 1st, up to 46°, 1.1 g; 2nd, 46-46.5°, 8.4 g (2-chloro-1-iodo-2-methylbutyne-3 with admixed 2-chloro-1-iodo-3-methylbutadiene-1,3); 3rd, 46.5-56°, 4.0 g; 4th, residue, 1.7 g.

Investigation of 46-46.5° (5 mm) fraction: d^{20}_4 1.7337, n^{20}D 1.5498, MR 41.97; Calc. 40.96.

Found %: Cl + I 71.37, 71.56. C_5H_6ClI. Calculated %: Cl + I 71.07.

IR spectrum: 776 v.s., 826 m., 854 m., 885 s., 920 s., 972 s., 1021 s., 1079 s., 1101 w., 1127 w., 1154 m., 1190 s., 1237 m., 1252 m., 1280 w., 1379 s., 1455 s., **1593** m., 2119 s., 2913 m., 2944 s., 2970 s., 3057 s., **3285** v.s. cm^{-1}.

As a result of treatment of 12 g of material for a day at room temperature with an alcoholic solution of KOH (4.2 g) we obtained 4.5 g of an oil which was separated by distillation (100 mm) into the following fractions: 1st, up to 90°, 0.5 g; 2nd, 90-100°, 1 g; 3rd, 100-105°, 1.2 g; 4th, residue, 1.3 g.

For the 90-100° (100 mm) fraction, we found: d_4^{20} 1.7142, $n^{20}D$ 1.5642.

IR spectrum: 779 s., 837 w., 852 w., **886** s., 904 v.s., 972 s., 1010 m., 1110 m., 1194 m., 1277 s., 1375 m., 1454 s., **1618** s., 2164 s., 2721 w., 2844 m., 2915 s., 2947 s., 2967 s., 3070 m., 3103 m. cm^{-1}.

We found in solution 34% of the chlorine and only 8.8% of the iodine in the sample.

For the 100-105° (100 mm) fraction, we found: d_4^{20} 1.7514, $n^{20}D$ 1.5680. The infrared spectrum contained the same frequencies as the lower boiling fraction, with similar intensities.

Investigation of the 46.5-56° (5 mm) fraction of the initial adduct; d_4^{20} 1.7157, $d^{20}D$ 1.5492.

Found %: Cl + I 71.87. C_5H_6ClI. Calculated %: Cl + I 71.07.

The infrared spectrum in the 3-5 μ region contained the same frequencies as the spectrum of the 46-46.5° (5 mm) fraction, and in addition a frequency at 3019 cm^{-1}. The frequency of the acetylene bond (2120 cm^{-1}) was of great intensity.

The infrared spectra were obtained with an IKS-12 spectrophotometer and in part with an IKS-14, in the region up to 5 μ with a LiF prism, and beyond that with a NaCl prism. Thickness of layer 0.033 mm. Usual designations.*

SUMMARY

1. The order of addition of iodine chloride to vinylacetylene and its close homologs has been investigated.

2. It has been shown that this order is qualitatively the same as the order of addition of bromine: vinylacetylene and propenylacetylene yield 1,4-adducts and adducts at the acetylenic bond, while vinylalkylacetylenes and isopropenylacetylene give adducts at the ethylenic bond, the latter with an admixture of 1,3-diene chloroiodide.

3. Chlorovinylmethyl- and chlorovinylethylacetylenes were obtained from the chloroiodo adducts of the vinylalkylacetylenes by the action of alcoholic alkali.

4. Peculiarities in the order of addition of iodine chloride to hydrocarbons of different structures have been explained by electron shifts in the conjugated enyne system under the influence of alkyl radicals.

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ORGANIC INSECTOFUNGICIDES

XLIII. SYNTHESIS OF α-OXIDES BY THE OXIDATION OF POLYCYCLIC HALO DERIVATIVES WITH HYDROGEN PEROXIDE

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One of the more general methods for obtaining α-oxides is the oxidation of unsaturated compounds with organic peracids. The oxidation of unsaturated compounds with benzoyl hydroperoxide was first proposed by N. A. Prilezhaev [1], and at the present time is used to synthesize extremely diverse compounds [2]. However, this method, extremely convenient for the laboratory preparation of small amounts of α-oxides, presents considerable difficulties when it is necessary to obtain substantial amounts of α-oxides, due to the relatively low stability of organic peracids, their high cost, etc. Large amounts of α-oxides are much more conveniently obtained by the oxidation of the proper unsaturated compounds with hydrogen peroxide, but the use of this oxidizing agent does not always give satisfactory results.

In view of the fact that certain cyclic α-oxides are powerful insecticides and find use in combatting plant pests, we decided to make a study of the oxidation of certain halo derivatives of polycyclic hydrocarbons using hydrogen peroxide. First we thought it would be interesting to study the oxidation of aldrin and isodrin for the purpose of obtaining dieldrin and endrin, which up to now have been obtained only by the oxidation of aldrin and isodrin with organic peracids [3-6], or with hydrogen peroxide in the presence of either pervanadic or pertungstic acid [7].
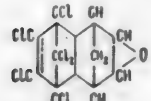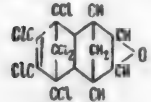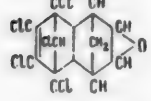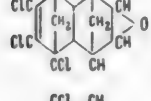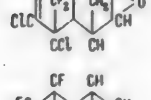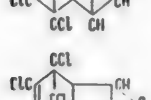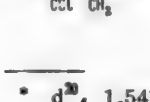
To obtain the corresponding oxides, we studied the oxidation of halo derivatives of polycyclic hydrocarbons with 27-30% hydrogen peroxide in 80-99% acetic acid. Here it was experimentally established that nearly all of the studied halo derivatives of polycyclic hydrocarbons give good yields of α-oxides when oxidized with hydrogen peroxide in acetic acid solution. Included in the compounds whose oxidation was studied were some that had been synthesized recently in our laboratory, namely, 1,2,3,4-tetrachloro-10,10-difluoro-1,4,5,8-diendomethylene-1,4,4a,5,8,8a-hexahydronaphthalene [8], 1,2-dichloro-3,4,10,10-tetrafluoro-1,4,5,8-diendomethylene-1,4,4a,5,8,8a-hexahydronaphthalene, 1,2,3,4-tetrachloro-1,4,5,8-diendomethylene-1,4,4a,5,8,8a-hexahydronaphthalene, and 1,2,3,4,10-pentachloro-1,4,5,8-diendomethylene-1,4,4a,5,8,8a-hexahydronaphthalene [9], which were also converted to the corresponding previously unknown α-oxides. With the exception of dieldrin and endrin, all of the compounds synthesized by us are new.

It is interesting to mention that the yields of the α-oxides depend to a large degree on their stability to water. The more stable the oxide, the higher the yield.

The compounds obtained by us and their properties are given in the table.

We will mention that the insecticidal activity of the oxides ran parallel to the activity of the starting unsaturated compounds.

Properties of Cyclic α-Oxides

Formula	Yield (in %)	Melting point	% Cl found	% Cl calc.	% C found	% C calc.	% H found	% H calc.
(Dieldrin)	83	176°	55.96	55.91	37.71	37.88	2.18	2.10
(Endrin)	63	240 (decomp)	—	—	37.47	37.88	2.30	2.10
	71	130—132	51.31	51.22	42.20	41.47	2.59	2.59
	83	106—107	—	—	45.53	45.50	2.34	2.20
	72	116	—	—	40.76	41.30	2.35	2.29
	83	M. p. 112—114° (7mm)*	—	—	45.83	45.71	2.49	2.54
	24	223—225	59.94	60.00	33.63	33.81	1.94	1.69

* d^{20}_4 1.5415, $n^{20}D$ 1.5002.

EXPERIMENTAL

The following conditions were used by us to oxidize halo derivatives of polycyclic hydrocarbons with hydrogen peroxide: a solution of the starting compound was placed in a flask, fitted with reflux condenser, mechanical stirrer and dropping funnel, and heated to 80-90°. Then 27-30% hydrogen peroxide was added gradually to the obtained solution, and the heating with stirring was continued for several hours. At the end of reaction the reaction mixture was cooled, the separated crystals of the oxide filtered, the mother liquor vacuum distilled to remove acetic acid and water, and the residue added to the earlier obtained product. In case the product was a liquid, the acetic acid and water were distilled off immediately after the end of reaction, and the oxide was fractionated in vacuo.

The oxidations were run using three times the theoretical amount of hydrogen peroxide.

The compounds obtained by us and their properties are given in the table.

SUMMARY

The oxidation of halo derivatives of polycyclic hydrocarbons with hydrogen peroxide in acetic acid solution was investigated. It was shown that this is a convenient way of obtaining the corresponding α-oxides in good yields. Most of the synthesized polycyclic α-oxides are new.

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ORGANIC INSECTOFUNGICIDES

XLIV. SYNTHESIS OF SOME AMIDES OF AROMATIC SULFONIC ACIDS

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As is known, various amides of sulfonic acids are used quite extensively at the present time in the treatment of greatly different infectious diseases. Amides and anilides of sulfonic acids also show a high bactericidal and bacteriostatic activity, and for this reason should find potential use in agriculture (for combatting plant pests) and for protecting various materials against destruction by microorganisms [1, 2].

With the above in mind, we made a special study of the fungicidal and bactericidal properties of the amides of various sulfonic acids and of some of their derivatives [1]. We thought it would be interesting to study first the various amides of p-chlorobenzene- and p-toluenesulfonic acids, since the first is a by-product in the manufacture of DDT, while the second is a by-product from the manufacture of saccharin, and it would be entirely practical to use them in the manufacture of any potentially valuable compounds. One of the more promising avenues in the synthesis of fungicides from sulfonamides of the above indicated acids is the preparation of various nitro-, halo- and halonitroanilides. This follows from the fact that many nitro- and halonitro derivatives in the aromatic series show substantial fungicidal activity, while others in this series find utility in agriculture as plant pest-control agents [3-6], and the introduction of the sulfonamido group into compounds of this type could enhance their fungicidal action. It would be especially interesting to prepare and study the various dinitroanilides of the indicated sulfonic acids, since these compounds have received very little study up to now [7, 8].

The new anilides of p-chlorobenzene- and p-toluenesulfonic acids were synthesized by us in conventional manner by the reaction of the corresponding sulfonyl chlorides either with an excess of the aniline or with 1 mole of the aniline in the presence of pyridine. The compounds obtained by us and their properties are given in the table. The nitroanilides of the corresponding sulfonic acids were obtained by nitrating the anilides with excess nitric acid in the presence of small amounts of sulfuric acid. The compounds obtained by us and their properties are given in the table. It is interesting to mention that the reaction of p-chlorobenzenesulfonyl chloride with 2,4,5-trichloroaniline in the presence of pyridine gave, together with the known [2] 2,4,5-trichloroanilide of p-chlorobenzenesulfonic acid, a substantial amount of bis-(p-chlorobenzenesulfonyl)-2,4,5-trichloroanilide, previously unknown.

Of the nitro derivatives of the sulfanilides synthesized by us, only the 2,4-dinitroanilide of 4-methyl-3-nitrobenzenesulfonic acid is described in [7], from which we prepared the previously unknown sodium, copper, and zinc salts. In view of the fact that nearly all of the sulfonic acid dinitroanilides synthesized by us are quite acidic, we prepared their practically water insoluble copper and zinc salts quite easily by reacting the corresponding sodium salts with either the sulfates or the chlorides of zinc and copper in water solution. The zinc and copper salts of the sulfanilides are moderately soluble in certain organic solvents, and are decomposed with relative ease by acids and ammonia. These salts show a quite high fungicidal activity. Most of the copper salts are green-colored solids with extremely high melting points. The zinc salts are yellow.

EXPERIMENTAL

1. Synthesis of substituted anilides of p-chlorobenzene- and p-toluenesulfonic acids. A chloroform solution of either p-chlorobenzene- or p-toluenesulfonyl chloride was added gradually to a chloroform solution of the chloroaniline or toluidine, and when all of the sulfonyl chloride had been added, the reaction mixture was heated on the water bath at 50° for 1-2 hours. Then, after standing for several hours, the chloroform was distilled off. The residue was washed with water and hydrochloric acid, and to achieve complete separation from excess amine, was dissolved in 5% aqueous NaOH solution. The sulfanilide was isolated from the NaOH solution by acidification with hydrochloric acid, dried, and recrystallized from a suitable solvent (in most cases, from methyl alcohol). We will mention that our p-chloroanilide of p-toluenesulfonic acid has m. p. 119-120°, whereas the literature m. p. is 95-96° [9]. It is possible that we have polymorphism in the present instance, mention of which is made in the literature for some other sulfonamides.

2. Preparation of nitroanilides of the sulfonic acids. As mentioned above, the nitration of the sulfanilides was run by us in the presence of sulfuric acid, using excess concentrated nitric acid. In most cases, we used 96% nitric acid containing 4% sulfuric acid. The finely powdered sulfanilide was added gradually to the nitric acid with good stirring and cooling to 0°. When all of the sulfanilide had been added, the temperature of the reaction mixture was gradually raised to 10-60° (depending on the compound being nitrated), and kept at this temperature for 2-4 hours. Then, after cooling, the reaction mixture was poured onto ice, and the precipitate filtered, washed with water, and dissolved with heating in 2% NaOH solution. The nitrosulfanilide was isolated from the NaOH by acidification with hydrochloric acid, filtered, washed with water, dried, and recrystallized from a suitable solvent. The obtained compounds and their properties are given in the table.

Properties of Anilides of p-Chlorobenzene- and p-Toluenesulfonic Acids

Name	Yield (in%)	Melting point	% N found	% N calc.	% Cl found	% Cl calc.
p-Chlorobenzenesulfonyl-3-chloro-4-nitroanilide	44	146—148°	8.20, 8.00	8.07	—	—
p-Chlorobenzenesulfonyl-2,4-dinitroanilide	89	178—180	11.93, 12.17	11.44	9.88	9.67
Sodium 4-methyl-3-nitrobenzenesulfonyl-2,4-dinitroanilide	85	—	13.63, 13.77	13.86	—	—
4-Methyl-3-nitrobenzenesulfonyl-2,4-dinitro-3-methylanilide	97	142—143	13.80, 14.47	14.14	—	—
p-Toluenesulfonyl-4-chloroanilide	80	119—120 *	4.75, 4.96	4.90	12.86	12.59
4-Methyl-3-nitrobenzenesulfonyl-4-chloro-2,6-dinitroanilide	96	180—181	13.36, 13.38	13.46	8.00, 8.03	8.53
Bis-(p-chlorobenzenesulfonyl)-2,4,5-trichloroanilide	26	> 250	2.93, 3.04	2.75	31.78	32.50
p-Chlorobenzenesulfonyl-3-toluidide	91	105—107	5.29, 5.31	4.96	12.51, 12.08	12.59
p-Chlorobenzenesulfonyl-3-methyl-2,4-dinitroanilide	54	148—149	11.29, 11.15	11.29	9.54, 9.24	9.54

* From [9], m. p. 95-96°.

3. Preparation of copper and zinc salts of nitrosulfanilides. To obtain the copper and zinc salts, a known weight of the sulfonic acid dinitroanilide was dissolved in exactly an equimolar amount of 2% NaOH solution with heating, and the obtained clear solution was then treated with either copper sulfate or zinc sulfate (chloride) solution. The obtained precipitate was filtered, washed with water, and dried. All of the salts were analyzed either for copper or for zinc. In this manner, we obtained the copper and zinc salts of the following sulfanilides: 2,4-dinitroanilide of p-chlorobenzenesulfonic acid, 2,4-dinitroanilide of 4-methyl-3-nitrobenzenesulfonic acid,

3-methyl-2,4-dinitroanilide of 4-methyl-3-nitrobenzenesulfonic acid, and 4-chloro-2,6-dinitroanilide of 4-methyl-3-nitrobenzenesulfonic acid. All of these compounds are new. We also obtained the previously unknown sodium salt of the 2,4-dinitroanilide of 4-methyl-3-nitrobenzenesulfonic acid, being a yellow crystalline compound. A water solution of this salt has pH 7.0.

Found %: N 13.63, 13.77. $C_{13}H_9O_8N_4SNa$. Calculated %: N 13.86.

4. Reaction of 2,4,5-trichloroaniline with p-chlorobenzenesulfonyl chloride. A solution of 25 g of p-chlorobenzenesulfonyl chloride in 100 ml of pyridine was added gradually at 10-20° to a solution of 24 g of 2,4,5-trichloroaniline in 100 ml of pyridine, and the obtained mixture was heated on the water bath at 70-80° for 4 hours. At the end of heating, the reaction mixture was diluted with water, and then treated with hydrochloric acid until all of the pyridine had been neutralized. The resulting precipitate was filtered, washed with water, and treated with 5% aqueous NaOH solution. The NaOH insoluble portion was filtered and washed with water. The substance was obtained as a white crystalline compound, not melting up to 250°. Yield 7 g.

Found %: N 3.04, 2.93; Cl 31.78. $C_{18}H_{10}O_4NS_2Cl_5$. Calculated %: N 2.75; Cl 32.50.

Acidification of the alkaline filtrate gave the 2,4,5-trichloroanilide of p-chlorobenzenesulfonic acid with m. p. 152-153° [2]. Yield 13.5 g (30%).

Found %: N 3.85, 3.88; Cl 38.03, 38.20. $C_{12}H_7O_2NSCl_4$. Calculated %: N 3.71; Cl 38.30.

SUMMARY

A number of new amides of p-chlorobenzene- and p-toluenesulfonic acids were synthesized for the purpose of studying their fungicidal properties.

It was shown that the reaction of 2,4,5-trichloroaniline with p-chlorobenzenesulfonyl chloride gives, besides the trichloroanilide, substantial amounts of the bis-(p-chlorobenzenesulfonyl)-trichloroanilide.

The previously unknown zinc and copper salts of the dinitroanilides of the sulfonic acids were prepared, which proved to be fungicides.

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AMINO KETONES OF THE 4-QUINAZOLINONE SERIES AS ANALOGS OF FEBRIFUGINE

I. DERIVATIVES OF ACETONE AND METHYL ETHYL KETONE

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The alkaloid febrifugine, isolated from the Chinese plant "Chan-Shan" or Dichroa febrifuga Lour., is 3-[β-keto-γ-(3-hydroxy-2-piperidyl)-propyl]-4-quinazolinone [1].
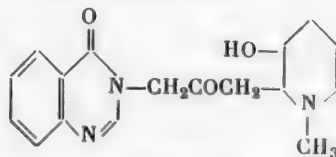
Febrifugine

As an antimalarial, it is 100 times stronger than quinine, but because of its high toxicity, being 300 times as toxic as quinine, it has failed to find extensive use as a curative. It is possible to theorize that among the analogs of febrifugine there should exist compounds that are good antimalarials and still possess a relatively low toxicity.

A large number of modifications of febrifugine have been prepared, in which different substituents have been introduced into the aromatic ring of the quinazolinone with retention of the complete skeleton of febrifugine [2]. Here some compounds with a high antimalarial activity were discovered, but not one of them had any advantages over febrifugine. It was mainly the quinazolinone ring and the hydroxypiperidine portion of the molecule that were subjected to change in the investigations, whereas the acetone linkage connecting the 4-quinazolinone in the 3-position with the 3-hydroxy-N-methylpiperidine in the 2-position was either hardly subjected to change or was changed but slightly.

It seemed both important and interesting to us to study the effect of the length of the ketonic chain linking the quinazolinone in the 3-position with a tertiary amine, which could be a simplified substitution for the N-methyl-3-hydroxypiperidine group, on the antimalarial activity. With this in mind, we undertook the problem of synthesizing compounds of general type (A).

(A)
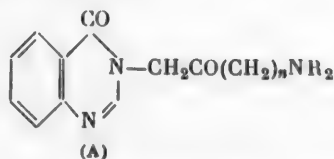
where; $n = 1, 2, 3, 4, 5$ and 10; $NR_2 = N(CH_3)_2$,

$N(C_2H_5)_2$, and

First we prepared some analogs of febrifugine in which n = 1, and which contained instead of the N-methyl-3-hydroxypiperidine group either the N-piperidino, N-morpholino or the N,N-diethylamino group. For their synthesis we condensed sodium 4-quinazolinonate with monochloroacetone [3] to yield 3-acetonyl-4-quinazolinone (I), which was then brominated in hydrobromic acid to the bromomethyl derivative, and this compound was then condensed with the tertiary amine.

$$ \text{(quinazolinone-NNa)} \xrightarrow{\text{ClCH}_2\text{COCH}_3} \text{N—CH}_2\text{COCH}_3 \quad (I) \longrightarrow $$

$$ \longrightarrow \text{N—CH}_2\text{COCH}_2\text{Br} \quad (II) \longrightarrow \text{N—CH}_2\text{COCH}_2\text{—NR}_2 . $$
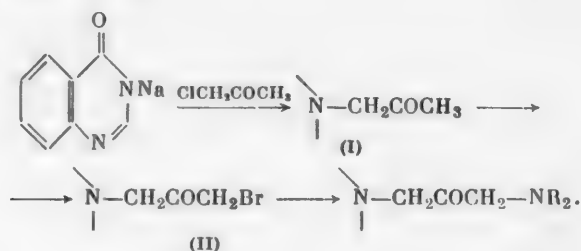
To prove that the bromination of the acetonylquinazolinone (I) goes as indicated above, we also obtained bromomethyl (4-quinazolinon-3-yl) methyl ketone by the counter synthesis, starting with (4-quinazolinon-3-yl) acetic acid [3]. This acid was converted through the acid chloride to the corresponding diazoketone, which gave (II) when decomposed with hydrogen bromide. Consequently, the direct bromination of the hydrobromide of (I) directs the attack of the bromine to the CH_3 group. Starting with diazomethyl (4-quinazolinon-3-yl) methyl ketone, we also prepared the hydrochloride of chloromethyl (4-quinazolinon-3-yl)methyl ketone.

Reaction of the bromomethyl ketone (II) with morpholine, piperidine, and diethylamine in anhydrous benzene medium gave smoothly the N-morpholinomethyl, N-piperidinomethyl and N,N-diethylaminomethyl (4-quinazolinon-3-yl)methyl ketones and their salts.

Subjected to biological testing in this series of compounds was the hydrochloride of N-piperidinomethyl (4-quinazolinon-3-yl)methyl ketone, which showed a slight antimalarial activity and a marked narcotic effect on mice.

The analogs of febrifugine having the methyl ethyl ketone chain were of special interest, since in them two C atoms are found between the $>$ CO and the N, the same as in febrifugine. However, great difficulties were encountered in the synthesis of these compounds (n = 2). An attempt has been made [3] to obtain such compounds by the Mannich reaction, involving the condensation of 3-acetonyl-4-quinazolinone (I) with formalin and secondary amines, but these attempts were not successful. Consequently, we proposed to accomplish this synthesis by condensing the quinazolinone with bromomethyl dialkylaminoethyl ketones.

$$ \text{(quinazolinone-NNa)} \xrightarrow{\text{BrCH}_2\text{COCH}_2\text{CH}_2\text{NR}_2} \text{N—CH}_2\text{COCH}_2\text{CH}_2\text{NR}_2 . \quad (A) $$
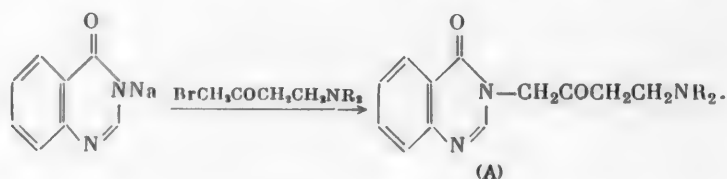
With some modifications of the literature procedure [5], we prepared the hydrobromides of bromomethyl, dimethylamino-, diethylamino-, dibutylamino- and N-piperidinoethyl ketones by the bromination of the corresponding ketones, and then condensed these compounds with 4-quinazolinone by heating in anhydrous alcohol containing an equivalent amount of sodium ethylate. Here all four of the starting bromomethyl dialkylamino ketones gave the same crystalline compound with m. p. 240°, independent of which ketone was taken for the condensation. This compound proved to be insoluble in water, in dilute acid and alkali solutions, and in the common organic solvents in the cold. When heated, it dissolved in pyridine, dimethylformamide and ethyl cellosolve. It dissolved in glacial acetic acid only when heated, and deposited on cooling without change, while from sulfuric acid solution it deposited as the disulfate. When analyzed, all four compounds had the same elementary composition, failing completely to agree with compounds of type "B", and all four had the same IR absorption spectrum. Starting with different dialkylamino (or N-piperidino) bromo ketones, the fact that we obtained the same compound, which we have named "C", and which is not the desired compound of type "B",

i.e., the dialkylaminoethyl (4-quinazolinon-3-yl)methyl ketone, indicated that in all four cases the reaction went differently than in all other cases of condensing 4-quinazolinone with bromomethyl dialkylamino ketones, in which n = 1, or n > 2, and where condensation went in the normal manner. Since, from the analysis, "C" did not contain the dialkylamino group, we postulated that the dialkylamino group is cleaved before reaction with the quinazolinone occurs. In connection with this, we decided to prepare first β-chloroethyl (4-quinazolinon-3-yl) methyl ketone, in order to replace later the β-halogen by the dialkylamino group. For this, starting with β-bromopropionic acid, we first converted the acid to the chloride, which was converted to diazomethyl β-chloroethyl ketone, and then to bromomethyl β-chloroethyl ketone. Condensation of 4-quinazolinone with the bromomethyl β-chloroethyl ketone in alcoholic sodium alcoholate medium gave a crystalline substance, devoid of halogen, with m. p. 240° after purification, and in no way differing from "C". In addition, we obtained a second substance, which was amorphous, contained halogen, and had m. p. 169-174°. All attempts to purify this substance proved unsuccessful. Condensation of the bromomethyl chloroethyl ketone with 4-quinazolinone in aqueous acetone medium, containing alkali, also gave the same substance "C" with m. p. 240°. The fact that the same substance "C" was also obtained when the condensation was run with the bromomethyl chloroethyl ketone indicated that the observed abnormalities in the course of the condensation are probably due to the bond instability of the amines [5] and of the halogen [6] in the β-position to the CO group, and the possibility of first forming vinyl (4-quinazolinon-3-yl) methyl ketone.

To verify this theory, the reaction mass from the condensation of 4-quinazolinone with the hydrobromide of bromomethyl 2-N-piperidinoethyl ketone, after dilution with water and removal of substance "C", was vacuum distilled. The distillate, which showed strongly alkaline to phenolphthalein, was acidified with hydrochloric acid to pH 3, and then evaporated to dryness in a dish on the water bath. Here a crystalline residue was obtained, which had a m. p. of about 232°, close to the melting point of piperidine hydrochloride, and which gave all of the reactions characteristic for piperidine hydrochloride, in which connection the amount of hydrochloride formed corresponded almost perfectly to the amount of piperidine ketone taken for reaction. As a result, the reaction course here indicated a complete cleavage of the amine, and consequently vinyl (4-quinazolinon-3-yl) methyl ketone should have been formed; however, substance "C" was not this compound, for it fails to show reaction for the double bond with either $KMnO_4$ or bromine. For this reason, we ran an experiment in which 4-quinazolinone was condensed with bromomethyl vinyl ketone, but in this case also only substance "C" was obtained. Later, in order to understand the course of the abnormal reaction, it was necessary to establish exactly the structure of substance "C". Since "C" does not contain halogen, is stable when heated, gives the disulfate with sulfuric acid (i.e., 1 mole of H_2SO_4 per mole of quinazolinone), and from the elementary analysis contains more carbon than is required by theory for the coupling of 1 mole of the quinazolinone with a side chain at carbon 4, it was postulated that 2 moles of the quinazolinone couple with one aliphatic chain.
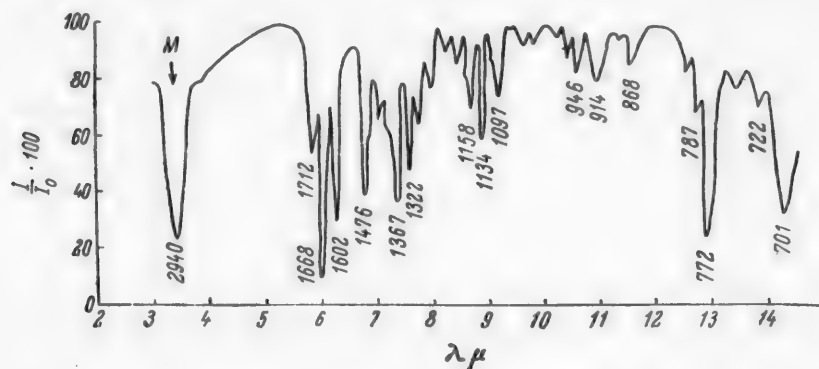
IR-absorption spectrum of (4-quinazolinon-3-yl) methyl (4-quinazolinon-3-yl) ethyl ketone.

Comparison of the UV-absorption spectrum* of substance "C" with that of the ethyl ester of (4-quinazo-linon-3-yl)acetic acid revealed that both compounds give completely identical absorption maxima at 266, 300, and 312 mμ, but the absorption intensity of substance "C" is twice that of the ethyl ester of (4-quinazolinon-3-yl)acetic acid. From these data it follows that substance "C" does not contain any systems of conjugated bonds that differ from those found in the quinazolinone ring (the positions of the bands coincide exactly with those of the quinazolinone ring), and that substance "C" contains 2 quinazolinone rings in its molecule, since the absorption intensity of substance "C" is twice that of the quinazolinonylacetic acid.

A study of the IR-absorption spectrum (see figure) of substance "C" as a mull in vaseline oil gave additional data as to its structure. Substance "C" failed to show any bands at 3000-3500 cm^{-1}, characteristic for the OH and NH bonds, and also any bands characteristic for exocyclic C=C bonds (1620-1650 cm^{-1}), but did show an absorption band characteristic for the amido carbonyl group $-CO-N<$, which must be attributed to the carbonyl group of 4-quinazolinone (1668 cm^{-1}), a band characteristic for conjugated double bonds in aromatic heterocycles $-C=N-C=C-$ (1602 cm^{-1}), and an absorption band characteristic for the CO group in aliphatic ketones (1712 cm^{-1}).

From all of this it followed that substance "C" should be (4-quinazolinon-3-yl)methyl (4-quinazolinon-3-yl)ethyl ketone (C), which was formed either as the result of the quinazolinone adding in alkaline medium to vinyl (4-quinazolinon-3-yl) methyl ketone at the double bond, or else bromomethyl vinyl ketone was formed first, which condensed with 4-quinazolinone, and then added a second molecule of 4-quinazolinone at the double bond.

(C)
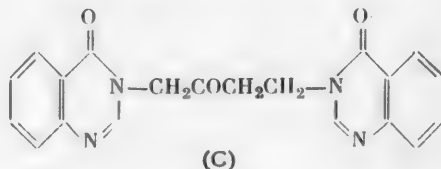
Such addition of different bases to the double bond of vinyl ketones is known [7]; the addition of aniline to methyl vinyl ketone with the formation of methyl β-anilinoethyl ketone is described in [8].

The elementary analysis data for substance "C" agreed well for (4-quinazolinon-3-yl)methyl (4-quinazolinon-3-yl)ethyl ketone. Analysis of the obtained disulfate also corresponded to the indicated structure. Determination of the molecular method by the Rast method gave a value of 399 (calculated: 360). Attempts to prepare either the oxime or the phenylhydrazone of substance "C" proved unsuccessful, possibly due to the complexity of the molecule, steric hindrance, and also the poor solubility of the substance in common solvents.

Substance "C" went into solution when heated with alcoholic caustic, and after distilling off the alcohol, the residue was treated with water and then with acid to pH 5; here a substance separated, which could not be purified, since it changed constantly when its purification was attempted either by reprecipitation or by recrystallization. Evaporation of the acetic acid mother liquor in vacuo to dryness yielded 4-quinazolinone with m. p. 214-216°. It is most probable that the action of the alkali caused cleavage of the quinazolinone with the formation of (4-quinazolinon-3-yl) methyl vinyl ketone, which then polymerized.

EXPERIMENTAL

3-Acetonyl-4-quinazolinone (I). To a solution of 12.8 g of sodium in 300 ml of anhydrous alcohol, prepared in a three-necked round-bottomed flask, fitted with mechanical stirrer and reflux condenser, was added 80 g of 4-quinazolinone, and after complete solution had been obtained, 64.5 g of freshly distilled monochloroacetone. Here, the temperature rose rapidly to 58° and yellow crystals began to deposit. Then the mixture was heated at 62-67° for 3 hours, until the reaction no longer showed alkaline to phenolphthalein.

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* Yu. N. Sheinker and co-workers were kind enough to run the spectral patterns on the compounds obtained by us, for which we are duly grateful.

The alcohol was vacuum distilled, and the residue was treated with 140 ml of water, filtered, washed with water, and dried. We obtained 80 g of 3-acetonyl-4-quinazolinone with m. p. 157-159° [3]. Another 6.2 g of substance was isolated by vacuum distillation of the mother liquor. Total yield 86.2 g (78.9%).

The oxime of 3-acetonyl-4-quinazolinone was obtained by heating the ketone with hydroxylamine hydrochloride and CH_3COOK in water at 80° for 7 hours. Light-yellow crystals, m. p. 189-190°.

Found %: N 19.33. $C_{11}H_{11}O_2N_3$. Calculated %: N 19.35.

3-Acetonyl-4-quinazolinone hydrobromide was obtained by saturating a solution of the ketone in CH_3COOH + HBr until acid to Congo red. M. p. 230-232°.

Found %: N 10.14, 10.17. $C_{11}H_{11}O_2N_2Br$. Calculated %: N 9.89.

Bromomethyl (4-quinazolinon-3-yl) methyl ketone (II). a) From 3-acetonyl-4-quinazolinone. Into a three-necked flask fitted with mechanical stirrer and thermometer was charged 580 ml of glacial acetic acid, and then 28 ml of 44% HBr solution in acetic acid was added. Then, with heating of the flask on the water bath and good stirring, 30 g of 3-acetonyl-4-quinazolinone was added, followed by the addition of a solution of 8 ml of bromine in 20 ml of acetic acid at 80°. The mixture decolorized after some time. The mixture was then stirred for another 2 hours at 60°, cooled in ice, water added, and the obtained precipitate was filtered, washed with water, and dried in the dark in a vacuum desiccator over sulfuric acid. The yield of bromomethyl (4-quinazolinon-3-yl) methyl ketone was 44.2 g. The crystalline compound sublimed without melting; it was purified by recrystallization from glacial acetic acid. Removal of the acetic acid from the mother liquor by vacuum distillation gave another 5 g of substance. Total yield 49.2 g (93.1%).

Found %: Br 43.66; N 7.69, 7.62. $C_{11}H_9O_2NBr \cdot HBr$. Calculated %: Br 44.14; N 7.74.

Treatment of the hydrobromide with $NaHCO_3$ solution until alkaline gave a white precipitate of the free base, which was separated, washed with water, dried, and recrystallized from chloroform. The pure bromomethyl (4-quinazolinon-3-yl) methyl ketone had m. p. 211-213°.

Found %: N 9.90; Br 28.75. $C_{11}H_9O_2N_2Br$. Calculated %: N 9.96; Br 28.42.

b) From 4-quinazolinone-3-acetic acid.* Hydrochloride of 4-quinazolinone-3-acetyl chloride. Into a three-necked flask, fitted with reflux condenser, thermometer, and mechanical stirrer, was charged 245 ml of absolute ether and 42 g of 4-quinazolinone-3-acetic acid with m. p. 238-240°, and then 245 ml of thionyl chloride was added at room temperature; here the temperature rose spontaneously to 40°. The whole went into solution at the start, and then crystals of the hydrochloride of 4-quinazolinone-3-acetyl chloride began to separate after which the stirring was continued for another hour; the precipitate was filtered, washed with dry ether, pressed, and dried in vacuo over sulfuric acid. Yield 49.2 g (92.7%), m. p. 232° (decompn.).

Diazomethyl (4-quinazolinon-3-yl)methyl ketone. A solution of 9.03 g of diazomethane in 350 ml of ether was placed in a flask, cooled in an ice-salt mixture, and then, with constant mechanical stirring, 14 g of 93% 4-quinazolinone-3-acetyl chloride hydrochloride was added, keeping the temperature between − 3 and − 4°; here a copious evolution of gases occurred, and the solution turned yellow; stirring was continued for another hour after all of the chloride had been added. The obtained diazoketone had m. p. 132-134°.

Bromomethyl (4-quinazolinon-3-yl) methyl ketone hydrobromide. The above-obtained reaction mixture was treated with 15 ml of glacial acetic acid and 38 ml of 44% HBr in glacial acetic acid. Here a copious evolution of nitrogen occurred and a crystalline precipitate deposited; stirring was continued for another hour, the ether decanted, and the yellow precipitate was filtered, washed with ether, and dried. We obtained 18 g of bromomethyl (4-quinazolinon-3-yl) methyl ketone hydrobromide. The free base isolated from this hydrobromide had m. p. 211-213°, and did not depress the melting point when mixed with the free base, obtained by the direct bromination of 3-acetonyl-4-quinazolinone.

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* 4-Quinazolinone-3-acetic acid was obtained by saponification of its ethyl ester, which had m. p. 83-84°, instead of the 76° reported by Baker [3].

The same as the above, the hydrochloride of chloromethyl (4-quinazolinon-3-yl)methyl ketone was obtained from 0.1 mole of 4-quinazolinone-3-acetyl chloride hydrochloride and 0.3 mole of diazomethane in 600 ml of absolute ether. The free base isolated from the hydrochloride using sodium bicarbonate had m. p. 194-195° (from alcohol). Yield 42%.

Found %: N 11.82; Cl 15.07. $C_{11}H_9O_2N_2Cl$. Calculated %: N 11.83; Cl 19.98.

N-Morpholinomethyl (4-quinazolinon-3-yl)methyl ketone. Into a three-necked flask, fitted with mechanical stirrer, thermometer and reflux condenser, was charged 40 ml of dry benzene and 4 g of dried bromomethyl (4-quinazolinon-3-yl) methyl ketone, and then, with constant stirring, 3 ml of morpholine was added, in which connection the temperature rose from 27 to 32°. The reaction mixture was heated on the water bath for 2 hours, and here everything went into solution at the start, after which a crystalline precipitate of morpholine hydrobromide began to deposit. At the end of heating, the mixture was stirred at room temperature for another 6 hours. Then 15 ml of water was added, after which the water layer was separated from the benzene layer, and extracted 4 times with benzene; the benzene solutions were combined, dried over sodium sulfate, the benzene distilled off, and the residue dissolved in 6.5 ml of anhydrous alcohol with heating. Cooling of the solution gave 0.85 g of crystalline N-morpholinomethyl (4-quinazolinon-3-yl) methyl ketone with m. p. 147-148°. Another 0.40 g of the free base was isolated from the mother liquor. M. p. 149-150° (from anhydrous alcohol).

Found %: N 14.62, 14.46. $C_{15}H_{17}O_3N$. Calculated %: N 14.62.

The last alcoholic mother liquor was treated with saturated alcoholic HCl solution until acid to Congo red. The obtained crystals of N-morpholinomethyl (4-quinazolinon-3-yl) methyl ketone hydrochloride were filtered (0.3 g), m. p. 154-156°. We isolated 0.27 g of the free base from these crystals. Total yield of the ketone was 1.52 g (37.2%). The free base is insoluble in water, and soluble in hot alcohol and benzene.

N-Piperidinomethyl (4-quinazolinon-3-yl) methyl ketone. The same as above, a solution of 8.4 g of bromomethyl (4-quinazolinon-3-yl) methyl ketone in 200 ml of benzene, contained in a three-necked flask, was treated with 7.5 ml of piperidine, after which the mixture was heated on the water bath for 3 hours. The crystals of piperidine hydrobromide obtained on cooling were filtered and washed with benzene (3.2 g, m. p. 230-232°). The filtrate was treated with 10 ml of water, the mixture stirred, the water layer separated, and the benzene layer distilled. The residue from the distillation was treated with 5 ml of anhydrous alcohol, and then acidified to Congo red with alcoholic HCl solution. Cooling gave 3.2 g of crystalline N-piperidinomethyl (4-quinazolinon-3-yl) methyl ketone hydrochloride, m. p. 157-160°, which after two recrystallizations rose to 166-167°. Another 2.1 g of the hydrochloride was isolated from the mother liquors. Total yield 5.3 g (55.2%).

Found %: N 12.79; Cl 10.97. $C_{16}H_{19}O_2N_3 \cdot HCl$. Calculated %: N 13.05; Cl 11.10.

After purification, the free base isolated from the hydrochloride had m. p. 114-115° (from alcohol).

Found %: N 14.49, 14.85. $C_{16}H_{19}O_2N_3$. Calculated %: N 14.72.

N,N-Diethylaminomethyl (4-quinazolinon-3-yl)methyl ketone hydrochloride was obtained the same as described above. Yield 50.3%, m. p. 144-145° (from alcohol). The compound crystallizes with 0.5 mole H_2O.

Found %: N 13.05, 13.07; Cl 11.24; H_2O 2.70. $C_{15}H_{19}O_2N_3 \cdot HCl \cdot 0.5H_2O$. Calculated %: N 13.18; Cl 11.12; H_2O 2.8.

Bromomethyl 2-diethylaminoethyl ketone hydrobromide. To a solution of 39.2 g of methyl 2-diethylaminoethyl ketone in 50 ml of glacial acetic acid was gradually added, with cooling, 70 g of 44% HBr solution in glacial acetic acid, followed by the addition of a solution of 43.2 g of bromine in 70 ml of glacial acetic acid at one time. The reaction mass was stirred at 20° for 2 hours until it had decolorized, after which the acetic acid was vacuum distilled. The sirupy residue was rubbed with half its weight of anhydrous alcohol; filtration gave 40.5 g of crystalline bromomethyl 2-diethylaminoethyl ketone hydrobromide. The mother liquor was diluted with ether until turbidity appeared, and then placed overnight in the refrigerator. Here an additional 8.1 g of the hydrobromide was obtained. Total yield 48.6 g (57.9%), m. p. 83° [4].

In a similar manner we obtained the hydrobromides of the following: bromomethyl 2-dimethylaminoethyl ketone (61%), m. p. 86-87°; bromomethyl 2-N-piperidinoethyl ketone (72.4%), m. p. 154-155°; and bromomethyl 2-dibutylaminoethyl ketone (66%), m. p. 121-123°.

Condensation of 4-quinazolinone with bromomethyl 2-diethylaminoethyl ketone hydrobromide. To a solution of 1.38 g of sodium in 44 ml of anhydrous ethanol, contained in a three-necked flask, fitted with mechanical stirrer, reflux condenser and thermometer, was added 4.44 g of 4-quinazolinone. To the obtained solution was added, at 48-50°, a solution of 9.09 g of bromomethyl 2-diethylaminoethyl ketone hydrobromide in 20 ml of anhydrous alcohol, which caused the temperature to rise to 55°; soon a pale yellow crystalline precipitate began to separate. After the reaction ceased to show alkaline to thymolphthalein, the stirring was continued for another 2 hours at 20°. Then the reaction mass was treated with 450 ml of cold water, and then with NaOH solution until alkaline to thymolphthalein. The crystalline substance was filtered and washed. It was free of halogen, had m. p. 232-234°, was insoluble in alcohol, ether, benzene and dioxane, and when heated was soluble in pyridine, ethyl cellosolve, dimethylformamide and glacial acetic acid. Two recrystallizations from ethyl cellosolve gave pure (4-quinazolinon-3-yl) methyl (4-quinazolinon-3-yl) ethyl ketone with m. p. 240°. Yield 1.8 g (65.2%, based on the quinazolinone).

Found %: C 66.48; H 4.64; N 15.57. $C_{20}H_{16}O_3N_4$. Calculated %: C 66.66; H 4.64; N 15.55.

Condensation of 4-quinazolinone with bromomethyl 2-dimethylaminoethyl ketone hydrobromide, under the same conditions as described above, gave a 58.4% yield of (4-quinazolinon-3-yl) methyl (4-quinazolinon-3-yl) ethyl ketone with m. p. 238-240°; in addition, we also recovered 40% of 4-quinazolinone with m. p. 214-215°. Similar results were obtained when 4-quinazolinone was condensed with bromomethyl 2-N-piperidino-ethyl ketone hydrobromide. The yield of (4-quinazolinon-3-yl) methyl (4-quinazolinon-3-yl) ethyl ketone was 53.4%. After removal of the compound with m. p. 240°, the aqueous alcohol mother liquor was distilled, and $^1/_5$ of the residue was neutralized with hydrochloric acid and evaporated on the water bath to dryness. We obtained 1.2 g (100%) of piperidine hydrochloride with m. p. 230-232°. Treatment of the hydrochloride with concentrated NaOH solution gave a layer of piperidine.

Condensation of 4-quinazolinone with bromomethyl 2-chloroethyl ketone. To a solution of sodium ethylate, prepared from 1.61 g of sodium and 80 ml of anhydrous ethanol, was added 10.3 g of 4-quinazolinone, and then 12.97 g of bromomethyl 2-chloroethyl ketone was added in one portion at 44°. The temperature rose to 52°, and crystals began to deposit; the reaction ceased to show alkaline to phenolphthalein. Stirring was continued for another 2 hours. Dilution with water gave 7.5 g (59.4%) of (4-quinazolinon-3-yl) methyl (4-quinazolinon-3-yl) ethyl ketone with m. p. 240° (from ethyl cellosolve). The aqueous alcohol filtrate was extracted 3 times with chloroform; removal of the solvent from the chloroform solution by distillation left a dark red oil which solidified when stirred with ether for a long time and gave 7.4 g of a yellow amorphous substance with m. p. 169-174°, insoluble in ether and ethyl acetate, and readily soluble in acetic acid and ethyl cellosolve; the compound contains halogen. We were unable to purify the substance.

The condensation of 4-quinazolinone with bromomethyl 2-chloroethyl ketone in aqueous acetone medium (3 : 2), with the addition of 46% KOH, at 40°, gave results comparable to the preceding; 33.2% of (4-quinazolinon-3-yl) methyl (4-quinazolinon-3-yl) ethyl ketone with m. p. 240°, and 4.5 g of a yellow amorphous substance containing halogen. Similar results were obtained when 4-quinazolinone was condensed with bromomethyl vinyl ketone.

(4-Quinazolinon-3-yl) methyl (4-quinazolinon-3-yl) ethyl ketone disulfate was obtained by dissolving the ketone in hot 25% H_2SO_4, followed by filtration and cooling of the filtrate. The disulfate separated as long needles with m. p. 210°; after washing with alcohol and drying, m. p. 227-229°.

Found %: S 11.90. $C_{20}H_{16}O_3N_4 \cdot 2H_2SO_4$. Calculated %: S 11.50.

Action of alcoholic alkali on (4-quinazolinon-3-yl) methyl (4-quinazolinon-3-yl) ethyl ketone. Three grams of substance "C" and 1.69 g of KOH in 50 ml of anhydrous alcohol was heated for 30 minutes at 50° until solution was obtained. The solution was filtered and the filtrate was evaporated in vacuo to dryness. The residue was treated with 32 ml of water; the obtained solution was filtered and acidified with acetic acid to pH 5; here 2.2 g of a yellow amorphous compound separated, which melted over a wide range (110-121°), had a polymeric nature, and could not be purified. The mother liquor was vacuum distilled and the residue was treated with water. We obtained 0.55 g of 4-quinazolinone as needle crystals with m. p. 214-216°.

SUMMARY

1. The bromination of 3-acetonyl-4-quinazolinone yields bromomethyl (4-quinazolinon-3-yl) methyl ketone.

2. The reaction of bromomethyl (4-quinazolinon-3-yl) methyl ketone in anhydrous benzene medium with diethylamine, morpholine, and piperidine leads to the smooth formation of the corresponding aminomethyl (4-quinazolinon-3-yl) methyl ketones.

3. The condensation of 4-quinazolinone in alkaline medium with bromomethyl 2-dialkylaminoethyl ketone, bromomethyl 2-N-piperidinoethyl ketone, or bromomethyl 2-chloroethyl ketone, does not go in the usual manner, but instead is accompanied by a complete cleavage of the amine, or of the piperidine, or of the halogen, from the ketone with the formation in all cases of the same compound with m. p. 240°.

4. Based on the analysis, spectral data, physical properties, and chemical reactions, the substance with m. p. 240° should be assigned the structure of (4-quinazolinon-3-yl) methyl (4-quinazolinon-3-yl) ethyl ketone. In all probability, this compound is formed either via the addition of 4-quinazolinone to the intermediate vinyl (4-quinazolinon-3-yl) methyl ketone or else through the formation of the intermediate bromomethyl vinyl ketone, followed by its condensation with 4-quinazolinone and the addition of a second 4-quinazolinone molecule to the double bond of the vinyl group.

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* Original Russian pagination. See C. B. Translation.

HYDROXY DERIVATIVES OF ANTHRACENE

V. THE STRUCTURE OF THE BISULFITE COMPOUNDS OF NITROSOANTHROLS

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In previous communications [1, 2] the bisulfite compounds of 1-nitroso-2-anthrol and 4-nitroso-1-anthrol were assigned the structure of 3,4-dihydro-1,2-anthraquinone-1-oxime-4-sulfonic acid (I) and 2,3-dihydro-1,4-anthraquinone-4-oxime-3-sulfonic acid (II), respectively.
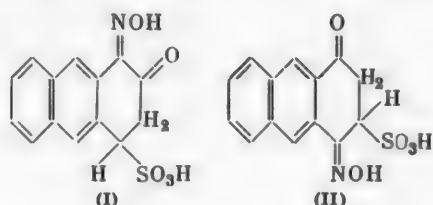
Additional data, supporting the validity of Formulas (I) and (II), were obtained when the spectra of the bisulfite compounds were studied. Earlier mention has already been made of the considerable difference in the ultraviolet spectra of 1-nitroso-2-anthrol, 1,2-anthraquinonedioxime, 1,2-anthra[3',4']furazan and 1,2-anthra[3',4']furoxan from those of their bisulfite compounds [2].

The change in the absorption spectra is no less sharp when the bisulfite compounds of 4-nitroso-1-anthrol (II) and 1,4-anthraquinonedioxime (III) are formed. If the absorption spectra of 4-nitroso-1-anthrol and 1,4-anthraquinonedioxime (Fig. 1, curves 2 and 3) are characterized by absorption maxima at about 230 and 310 mμ, then for the bisulfite compounds of (II) and (III) these maxima (Fig. 2, curves 2 and 3) are either degenerate or completely absent, and the principal absorption maximum is located around 270 mμ.

Formulas (II) and (III) permit explaining the change in the spectra by assuming that the carbon—carbon bond in the quinoid ring becomes saturated as the result of adding the bisulfite. To verify this assumption it was necessary to compare the absorption spectra of 1,4-anthraquinone and 2,3-dihydro-1,4-anthraquinone (IV).
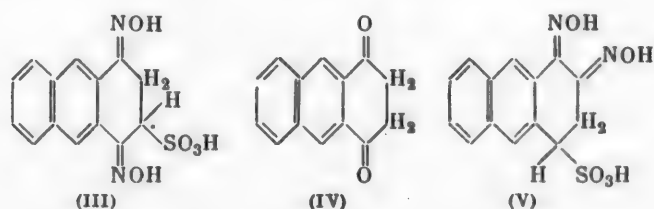
It proved that going from 1,4-anthraquinone (Fig. 1, curve 1) to the 2,3-dihydro derivative (IV) (Fig. 2, curve 1) is accompanied by the same change in the absorption curve as is observed for the bisulfite compounds of (II) and (III). A maximum at 265-270 mμ is characteristic for the system of bonds found in (IV), where two carbonyl groups are found in conjugation with the aromatic portion of the molecule. In derivatives of 3,4-dihydro-1,2-anthraquinone where one carbonyl group does not take part in the conjugation, the maximum is shifted by 35-40 mμ toward shorter wavelengths. Thus, for example, λ_{max} for 2,3-dihydro-1,4-anthraquinone-dioxime-3-sulfonic acid (III) is at 270 mμ, while for 3,4-dihydro-1,2-anthraquinonedioxime-4-sulfonic acid (V) it is at 233 mμ [2].
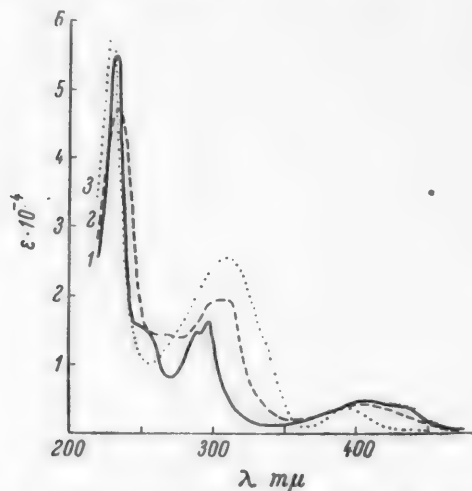
Fig. 1. Ultraviolet absorption spectra (in alcohol);
1) 1,4-anthraquinone, 2) 4-nitroso-1-anthrol,
3) 1,4-anthraquinonedioxime.
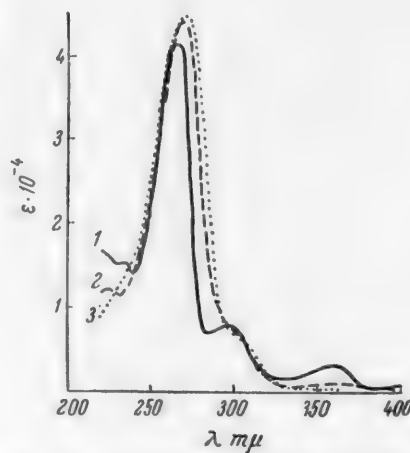
Fig. 2. Ultraviolet absorption spectra (in alcohol); 1) 2,3-dihydro-1,4-anthraquinone (IV), 2) bisulfite compound of 4-nitroso-1-anthrol (II), 3) bisulfite compound of 1,4-anthraquinonedioxime (III).

Infrared Spectra of Bisulfite Compounds (Crystallohydrates of the Sodium Salts)

Expt. No.	Com-pound	Frequency (in cm^{-1})
1	I	2854 (ср), 2892 (сл), 2982 (с), 3111 (с), 3198 (сл), 3323 (с), 3436) (ср)
2	II	2840 (сл), 2917 (сл), 3008 (сл), 3040 (сл), 3127 (ср), 3376 (с)
3	III	2848 (ср), 2922 (ср), 2975 (сл), 3025 (ср), 3046 (сл), 3074 (сл), 3230 (ср), 3430 (с)
4	V	2755 (сл), 2857 (с), 2895 (ср), 2945 (сл), 3028 (сл), 3050 (сл), 3167 (сл), 3445 (с)
5	V *	2750 (ср), 2843 (с), 2907 (сл), 2937 (сл), 3022 (сл), 3040 (ср), 3162 (сл), 3350 (ср), 3433 (ср)
6	VI	2625 (сл), 2952 (ср), 2981 (с), 3049 (с), 3350 (с), 3478 (ср)
7	VII	2625 (сл), 2910 (ср), 2946 (ср), 2998 (сл), 3040 (сл), 3060 (сл), 3270 (ср), 3490 (с)

* The substance was dried until the water of crystallization had been removed.

Legend: с — strong, ср — medium, сл — weak.

When the infrared spectra of compounds (I) and (II) were taken in the 2500-3600 cm^{-1} region, bands were found at 2840-2950 cm^{-1}, which could be considered as belonging to the C—H valence vibrations in the CH$_2$ groups. The same bands also exist in the spectra of other bisulfite compounds (I — III and V — VII) (see table). The presence of CH$_2$ groups in the bisulfite compounds of the nitrosoanthrols is well explained by Formulas (I) and (II).

(VI)   (VII)
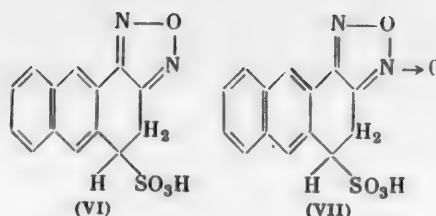
As a result, a study of the ultraviolet and infrared spectra of the bisulfite compounds supports the validity of the structure proposed for them.

EXPERIMENTAL

1,4-Anthraquinone. A solution of 14 g of potassium nitrosodisulfonate [3] in 200 ml of 3% monosodium phosphate solution and 40 ml of water was added to a solution of 4 g of 1-anthrol in 300 ml of acetone at 15 to 20°. Within several minutes a precipitate began to separate, and after 1 hour the mixture was diluted with 1 liter of water, allowed to stand overnight, and the crystals of 1,4-anthraquinone filtered and washed. Yellow needles with m. p. 206-208° (decompn.), yield 4.12 g (96%). After vacuum sublimation and crystallization from acetone, m. p. 223-224°; literature [4]: m. p. 220-225°.

2,3-Dihydro-1,4-anthraquinone (IV) was prepared by the procedure described in [5]. 1,4-Anthraquinone was reduced in aqueous ether medium with sodium hydrosulfite, followed by extraction of the 1,4-dihydroxy-anthracene from the ether layer, after which it was recrystallized from aqueous alcohol, heated for 10 minutes in vacuo at 210-220°, and cooled rapidly. The product was extracted from the melt with chloroform, and then recrystallized first from alcohol, and then from gasoline. Coarse brownish-yellow plates, m. p. 170° (decompn.); literature [5]: m. p. 170-171°.

The bisulfite compounds (I — III and V — VII) were obtained as the sodium salts, using the procedure described in our previous papers [1, 2].

Spectrometry. A SF-4 spectrophotometer was used to take the ultraviolet spectra at 5 mμ intervals, using alcohol solutions of the compounds, at concentrations of 10^{-4} and $0.2 \cdot 10^{-4}$ M. An IKS-11 spectrometer was used to take the infrared spectra, using a LiF prism, and running the compounds as mulls in hexachloro-propylene. The crystallohydrates of the bisulfite compounds were employed for the measurements; removal of the water of crystallization has little effect on the position of the bands at 2840-2950 cm^{-1} (see table, Nos. 4 and 5).

SUMMARY

1. In going from 1,4-anthraquinone to 2,3-dihydro-1,4-anthraquinone the same change in the ultra-violet spectrum is observed as when the transition is to the bisulfite compounds of 4-nitroso-1-anthrol and 1,4-anthraquinonedioxime.

2. The spectral studies support the fact that 4-nitroso-1-anthrol and 1-nitroso-2-anthrol react in the quinoneoxime form with bisulfite, and add the latter at the carbon — carbon double bond in the quinoid ring.

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* Original Russian pagination. See C. B. Translation.

REACTION OF TROPYLIUM SALTS WITH ALDEHYDES

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Tropylium salts react readily with various nucleophilic agents [1, 2]. The reaction of tropylium salts with aldehydes is studied in this paper.

Due to the lability of the α-hydrogen atoms, aldehydes readily exchange the hydrogen for deuterium [3], suffer bromine substitution, and enter into various condensations.

$$-\overset{\underset{|}{H}}{\underset{|}{C}}-CHO + D^+ \longrightarrow \underset{D}{\overset{}{>}}C-CHO + H^+.$$

We found that the tropylium cation is also capable of reacting with aldehydes. Even at room temperature (more rapidly and with better yields if short heating is used), one of the α-hydrogen atoms of the aldehyde is replaced by the cycloheptatrienyl radical.

The reaction of tropylium bromide with acetaldehyde, propionaldehyde, and isobutyraldehyde, containing respectively three, two and one α-hydrogen atoms, proceeds according to this scheme. In all cases, the mono-substituted reaction products were obtained, namely, cycloheptatrienylacetaldehyde (I), α-cycloheptatrienyl-propionaldehyde (II), and α-cycloheptatrienylisobutyraldehyde (III):

$$\underset{(I)}{C_7H_7—CH_2CHO} \qquad \underset{(II)}{C_7H_7—CH(CH_3)CHO} \qquad \underset{(III)}{C_7H_7—C(CH_3)_2CHO.}$$
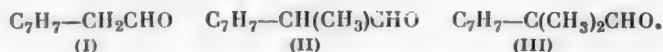
Tropylium salts also react under the same conditions with isovaleraldehyde, enanthaldehyde and cyclamen aldehyde [hydrocinnamaldehyde]. At the same time benzaldehyde, not containing any α-hydrogen atoms, fails to react with tropylium salts, even on prolonged heating.

The structure of cycloheptatrienylacetaldehyde and α-cycloheptatrienylisobutyraldehyde was verified by showing them to be identical with the aldehydes formed by the addition of tropylium salts to the proper vinyl ethers [4].

$$C_7H_7{}^+Br^- + CH_2=CHOC_2H_5 \xrightarrow{H_2O} C_7H_7—CH_2CHO$$

$$C_7H_7{}^+Br^- + (CH_3)_2C=CHOC_2H_5 \xrightarrow{H_2O} C_7H_7—\underset{\underset{CH_3\ \ \ CH_3}{\diagup\diagdown}}{C}—CHO$$
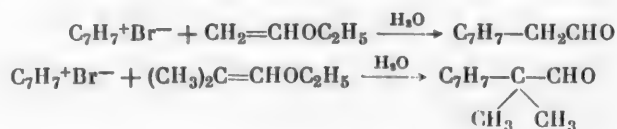
The characteristic absorption frequency of the carbonyl group in the infrared spectra of the obtained aldehydes lies in the range 1730-1740 cm^{-1}; this indicates that conjugation of the C=O group with the C=C double bonds is absent.

The ultraviolet spectra of all three aldehydes show an absorption maximum at 260 mμ, which coincides with the absorption maximum for the unsubstituted cycloheptatriene (λ_{max} 260 mμ); log ε = 3.63 for cycloheptatrienylacetaldehyde, 3.38 for α-cycloheptatrienylpropionaldehyde, and 3.32 for α-cycloheptatrienylisobutyraldehyde.

As a result, it was shown that tropylium salts react under mild conditions with aldehydes containing α-hydrogen atoms; here tropylation of the aldehyde occurs and the formation of a new C—C bond takes place.

EXPERIMENTAL

Cycloheptatrienylacetaldehyde (I). To a solution of 1.5 g of tropylium bromide in 25 ml of water, heated on the water bath (bath temperature 40-45°), was gradually added, with stirring, a solution of 6 g of acetaldehyde in 25 ml of alcohol. After reaction for 40 minutes, the solution was cooled and extracted with ether. The ether extracts were washed with water, and then dried over $MgSO_4$. After distilling off the ether we obtained 0.34 g (29%) of crude cycloheptatrienylacetaldehyde with b. p. 75-77° (4 mm), $n^{20}D$ 1.5265.

Dimedon derivative, m. p. 147° (from alcohol).

Found %: C 75.43, 75.47; H 8.03, 8.04. $C_{25}H_{32}O_4$. Calculated %: C 75.72; H 8.13.

The mixed melting point with the dimedon derivative of the aldehyde obtained by reacting the tropylium salt with vinyl ethyl ether [4] was not depressed.

α-Cycloheptatrienylpropionaldehyde (II). 1) To a solution of 4.28 g of tropylium bromide in 50 ml of water, heated on the water bath (bath temperature 55-60°), was slowly added, with stirring, 5.8 g of propionaldehyde. After 30 minutes of reaction the solution failed to contain any of the starting tropylium salt (absence of a precipitate with H_2PtCl_6). The reaction mixture was cooled, extracted with ether, and the ether extracts were washed with water and then dried over $MgSO_4$. The solvent was distilled off and the residue was vacuum distilled to give 2.81 g (75.9%) of α-cycloheptatrienylpropionaldehyde with b. p. 64-68.5° (2 mm), which after redistillation had the following constants.

B. p. 68.5° (2 mm), $n^{20}D$ 1.5216, d^{20}_4 1.0023, MR 45.67; calc. 44.79.*

Found %: C 80.80, 80.53; H 8.32, 8.18. $C_{10}H_{12}O$. Calculated %: C 81.04; H 8.16.

2,4-Dinitrophenylhydrazone, m. p. 143° (from alcohol).

Found %: C 58.40, 58.93; H 4.85, 4.82. $C_{16}H_{16}O_4N_4$. Calculated %: C 58.53; H 4.91.

2) To a solution of 3.42 g of tropylium bromide in 15 ml of aqueous alcohol (2:1) was added 1.5 g of propionaldehyde. After a day, the alcohol and excess starting aldehyde were vacuum distilled. The aqueous solution was extracted with ether. The ether extracts were washed with water and dried over $MgSO_4$. Removal of the solvent by distillation gave 0.52 g (17.5%) of α-cycloheptatrienylpropionaldehyde with b. p. 72-80° (3 mm), $n^{20}D$ 1.5230.

2,4-Dinitrophenylhydrazone, m. p. 143° (from alcohol).

α-Cycloheptatrienylisobutyraldehyde (III). 1) To a solution of 3.42 g of tropylium bromide in 50 ml of water, heated on the water bath (bath temperature 50-60°), was slowly added, with stirring, 2.5 g of isobutyraldehyde. After 30 minutes of reaction the solution was cooled and extracted with ether. The ether extracts were washed with water and dried over $MgSO_4$. After distilling off the solvent in vacuo, followed by fractional distillation, we obtained 2.71 g (83.3%) of α-cycloheptatrienylisobutyraldehyde.

B. p. 74° (3 mm), $n^{20}D$ 1.5172, d^{20}_4 0.9789, MR 50.14; calc. 49.41.

Found %: C 81.13, 81.24; H 8.67, 8.79. $C_{11}H_{14}O$. Calculated %: C 81.44; H 8.70.

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* In all cases the MR was calculated without taking into consideration the exaltation for conjugation of the double bonds and without correction for the seven-membered ring.

2,4-Dinitrophenylhydrazone, m. p. 150° (from alcohol).

Found %: C 59.65, 59.38; H 5.07, 5.31. $C_{17}H_{18}O_4N_4$. Calculated %: C 59.64; H 5.30.

The mixed melting with the 2,4-dinitrophenylhydrazone of the aldehyde, obtained by reacting β,β-dimethylvinyl ether with the tropylium salt, was not depressed.

2) To a solution of 1.71 g of tropylium bromide in 10 ml of water was added 1 g of isobutyraldehyde. After a day, the solution was extracted with ether. The ether extracts were washed with water and dried over $MgSO_4$. Removal of the solvent by distillation gave 1.15 g (70%) of the cycloheptatrienylisobutyraldehyde; b. p. 82 83° (5 mm), $n^{20}D$ 1.5141. After redistillation: b. p. 77° (4 mm), 79.5° (5 mm), $n^{20}D$ 1.5169.

2,4-Dinitrophenylhydrazone, m. p. 150° (from alcohol).

SUMMARY

1. It was shown that tropylium salts react readily with aldehydes containing α-hydrogen atoms.

2. The reaction of tropylium bromide with acetaldehyde, propionaldehyde, and isobutyraldehyde gave cycloheptatrienylacetaldehyde, α-cycloheptatrienylpropionaldehyde, and α-cycloheptatrienylisobutyraldehyde, respectively.

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* Original Russian pagination. See C. B. Translation.

PREPARATION OF 1-METHOXY-4-PENTEN-3-ONE AND ITS USE IN DIENIC SYNTHESIS

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1-Methoxy-4-penten-3-one has been obtained by heating 1,5-dimethoxy-3-pentanone in vacuo in the presence of p-toluenesulfonic acid [1].

$$CH_3OCH_2CH_2CH=CHCH_2Cl$$
$$(I)$$

$$CH_3OCH_2CH_2CHCH=CH_2$$
$$Cl \quad (II)$$

$$CH_3OCH_2CH_2CH=CHCH_2OH$$
$$(III)$$

$$CH_3OCH_2CH_2CHCH=CH_2$$
$$OH \quad (IV)$$

$$CH_3OCH_2CH_2COCH=CH_2$$
$$(V)$$
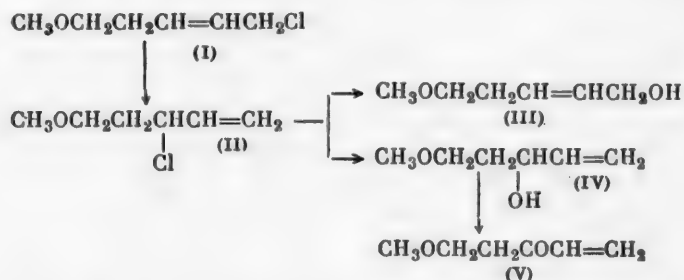
1-Methoxy-4-penten-3-one was synthesized by a different route in this paper. The addition of chloromethyl ether to 1,3-butadiene in the presence of zinc chloride [2] gave a mixture of isomeric methoxychloropentenes (I) and (II). Catalytic isomerization of the primary chloride (I) in the presence of zinc chloride [3] gave the secondary chloride (II) in 60% yield. Hydrolysis of the secondary chloride (II) with aqueous sodium carbonate solution [4] gave a mixture of isomeric methoxypentenols (III) and (IV), which on fractional distillation gave the pure alcohols. Oxidation of alcohol (IV) gave 1-methoxy-4-penten-3-one (V).

We first used manganese dioxide as the oxidizing agent, and here the yield of ketone (V) was 67%. Determination of the density of the ketone, and also the low yield (60%) of the adduct with cyclopentadiene, indicated that the ketone still contained the starting alcohol as impurity. Next we tried chromic anhydride as the oxidizing agent. In these experiments we obtained the pure ketone in variable yields (35-50%), but a large amount of glassy residue always remained in the distillation flask, which, undoubtedly, was the polymer of the obtained ketone. Consequently, in subsequent experiments we introduced some changes in the method of operation: the ketone was extracted with chloroform, and hydroquinone was added as inhibitor, both during the drying of the chloroform solution and when the ketone was distilled. In these experiments the pure ketone was obtained in 64% yield. Even better results (90% yield) were obtained when the alcohol was oxidized with a complex composed of pyridine and chromic anhydride [5].

Condensation of ketone (V) with cyclopentadiene gave 1-(β-methoxypropionyl)-2,5-endomethylene-3-cyclohexene (VI) in 76% yield. By reacting ketone (V) with 1,3-cyclohexadiene we obtained 1-(β-methoxypropionyl)-2,5-endoethylene-3-cyclohexene (VII) in 72% yield.

$$
\begin{array}{cc}
\text{(VI)} & \text{(VII)}
\end{array}
$$

CH
CH   CHCOCH$_2$CH$_2$OCH$_3$
CH   CH$_2$
CH   CH$_2$
CH
(VI)

CH
CH CH$_2$ CHCOCH$_2$CH$_2$OCH$_3$
CH CH$_2$ CH$_2$
CH
(VII)
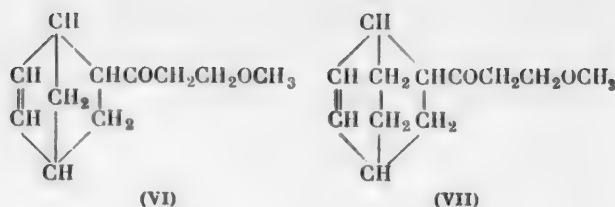
EXPERIMENTAL

Preparation of isomeric methoxychloropentenes. A mixture of 306 g of chloromethyl ether (b. p. 58-59°) and 3 g of freshly fused, finely divided zinc chloride was charged into a flask, fitted with a thermometer and both inlet and outlet tubes. The flask was cooled in a mixture of ice and salt. When the temperature of the flask contents had reached − 10°, we began to pass 1,3-butadiene into the mixture, adjusting its rate in such a manner that the temperature of the mixture did not rise above − 10°. The amount of 1,3-butadiene absorbed in 6 hours was 248 g. The reaction mixture was held at − 15° to − 7° for 2 days, and then allowed to stand at room temperature for 3 days. After this the mixture was diluted with 250 ml of ether, washed with water (6 × 100 ml), and dried over CaCl$_2$. The ether was distilled off, and the residue was fractionally distilled in vacuo through a column packed with glass rings (height 60 cm). We obtained 158.5 g of 1-methoxy-3-chloro-4-pentene (b. p. 31-32° at 8 mm, d$^{20}_4$ 0.9774, n^{20}D 1.4378) and 212 g of 1-methoxy-5-chloro-3-pentene (b. p. 51-52° at 8 mm, d$^{20}_4$ 1.0077, n^{20}D 1.4545). These values are close to the literature constants [2, 3, 6, 7]. The total yield of methoxychloropentenes was 72%.

Isomerization of 1-methoxy-5-chloro-3-pentene to 1-methoxy-3-chloro-4-pentene. A mixture of 67.2 g of 1-methoxy-5-chloro-3-pentene and 0.67 g of freshly fused, finely divided zinc chloride was charged into a flask, fitted with a column packed with glass rings (height 60 cm). Then the vacuum was turned on, and the flask was heated in a glycerin bath. The amount of distillate collected in 2 hours was 47.6 g (b. p. 38-39° at 13 mm, n^{20}D 1.4400), which when redistilled gave 40.5 g (60%) of pure 1-methoxy-3-chloro-4-pentene with b. p. 35-36° at 12 mm, and n^{20}D 1.4380.

Hydrolysis of 1-methoxy-3-chloro-4-pentene. A mixture of 650 ml of water, 100 g of sodium carbonate and 104 g of 1-methoxy-3-chloro-4-pentene was charged into a flask, fitted with a stirrer and reflux condenser. The flask was heated for 9 hours on the boiling water bath. Then the mixture was cooled and saturated with potassium carbonate. The upper layer was separated, while the water layer was extracted with ether (6 × 50 ml). The ether extracts were combined with the earlier separated layer, and the solution dried over MgSO$_4$. The ether was distilled off, and the residue was fractionally distilled in vacuo through a column packed with glass rings (height 60 cm). We obtained 26.3 g of 1-methoxy-4-penten-3-ol (b. p. 56° at 7 mm, d$^{20}_4$ 0.9332, n^{20}D 1.4386) and 36.7 g of 1-methoxy-3-penten-5-ol (b. p. 84° at 7 mm, d$^{20}_4$ 0.9531, n^{20}D 1.4510) [4, 6]. The total yield of the alcohols was 70%.

Oxidation of 1-methoxy-4-penten-3-ol with manganese dioxide. A charge of 230 g of manganese dioxide (obtained by the procedure of [8]), 1800 ml of dry acetone and 23.2 g of 1-methoxy-4-penten-3-ol was placed in a dark glass bottle. The bottle was shaken mechanically at room temperature for 25 hours. The solution was filtered, and the precipitate was washed repeatedly with dry acetone, after which the acetone was removed by distillation through a 60 cm Vigreux column. The residue was vacuum distilled. We obtained 15.4 g (67%) of 1-methoxy-4-penten-3-one with b. p. 63-65° (20 mm), d$^{20}_4$ 0.9435, n^{20}D 1.4368 [1].

Oxidation of 1-methoxy-4-penten-3-ol with chromic anhydride in sulfuric acid. A solution of 5.0 g of 1-methoxy-4-penten-3-ol in 12 ml of acetone was placed in a flask, fitted with a stirrer, thermometer, reflux condenser and dropping funnel. With vigorous stirring and cooling of the flask in an ice-water mixture, a solution of 3.75 g of chromic anhydride in 10 ml of water and 3 ml of concentrated sulfuric acid was added from the dropping funnel. The oxidizing agent was added at such a rate that the temperature of the mixture did not exceed 10°. The stirring was then continued for another 30 minutes, after which the mixture was diluted with 120 ml of water and extracted with chloroform (5 × 50 ml). The chloroform solution was washed with sodium carbonate solution, then with water, and dried over MgSO$_4$ in the presence of hydroquinone. The chloroform was distilled off, while the residue was vacuum distilled in the presence of hydroquinone. We obtained 3.15 g (64%) of 1-methoxy-4-penten-3-one with b. p. 55-56° at 13 mm, d$^{20}_4$ 0.9538, n^{20}D 1.4380.

Oxidation of 1-methoxy-4-penten-3-ol with the complex of pyridine and chromic anhydride. Five grams of chromic anhydride was added gradually to 40 ml of dry pyridine. When $1/3$ of the chromic anhydride had been added, the mixture showed considerable heat evolution, so the remainder of the chromic anhydride was added with cooling in ice. The obtained complex was stirred with a solution of 5.0 g of 1-methoxy-4-penten-3-ol in 40 ml of dry pyridine. The mixture was stirred thoroughly, and then allowed to stand at room temperature for 15 hours. After this the mixture was diluted with 100 ml of water, acidified with dilute hydrochloric acid, and extracted with chloroform (6 × 50 ml). The chloroform solution was washed with sodium carbonate solution, then with water, and dried over $MgSO_4$ in the presence of hydroquinone. The chloroform was distilled off, while the residue was vacuum distilled in the presence of hydroquinone. We obtained 4.4 g (90%) of 1-methoxy-4-penten-3-one with the following constants: b. p. 59-60° (17 mm), d^{20}_4 0.9551, $n^{20}D$ 1.4380.

Addition of 1-methoxy-4-penten-3-one to cyclopentadiene. A charge of 10.4 g of 1-methoxy-4-penten-3-one and 0.1 g of hydroquinone was placed in a flask, fitted with a reflux condenser. Then 8.5 g of ice-cooled cyclopentadiene (b. p. 40-42° at 760 mm) was added gradually through the condenser. Marked self-heating of the mixture was observed, and the flask had to be cooled in water. Then the flask was heated on the boiling water bath for 1 hour, after which the mixture was vacuum distilled. We obtained 12.05 g (76%) of 1-(β-methoxypropionyl)-2,5-endomethylene-3-cyclohexene with b. p. 120-121° (11 mm), d^{20}_4 1.0354, $n^{20}D$ 1.4836.

Found %: C 73.24, 73.27; H 9.11, 9.11. $C_{11}H_{16}O_2$. Calculated %: C 73.30; H 8.95.

Addition of 1-methoxy-4-penten-3-one to 1,3-cyclohexadiene. A mixture of 11.4 g of 1-methoxy-4-penten-3-one and 0.1 g of hydroquinone was placed in a flask fitted with a reflux condenser. Then 12.0 g of 1,3-cyclohexadiene (b. p. 79-80° at 737 mm, d^{20}_4 0.8413, $n^{20}D$ 1.4748) was added through the condenser. Self-heating of the mixture was observed. The flask was heated on the boiling water bath for 7 hours, after which the mixture was vacuum distilled. We obtained 14.24 g (72%) of 1-(β-methoxypropionyl)-2,5-endoethylene-3-cyclohexene with b. p. 142-144° (14 mm), d^{20}_4 1.0431, $n^{20}D$ 1.4920.

Found %: C 74.27, 74.11; H 9.41, 9.47. $C_{12}H_{18}O_2$. Calculated %: C 74.19; H 9.34.

SUMMARY

1. 1-Methoxy-4-penten-3-ol was synthesized and its oxidation to 1-methoxy-4-penten-3-one was studied.

2. The dienic synthesis of 1-methoxy-4-penten-3-one with cyclopentadiene and with 1,3-cyclohexadiene was run.

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SYNTHETIC ANTISPASMODICS

SYNTHESIS OF 1-PHENYL-1-CYCLOHEXYL-3-(2,5-DIMETHYL-N-PIPERIDINO)-1-PROPANOL

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To synthesize compounds close in structure to the effective antispasmodic artane we used 2,5-dimethyl-4-piperidone (II) [1, 2], obtained by the I. N. Nazarov reaction from ammonia and propenyl isopropenyl ketone (I). The latter is an intermediate in the synthesis of the analgesics promedol, isopromedol, and α-promedol [3].

2,5-Dimethyl-4-piperidone (II) was converted to 2,5-dimethylpiperidine (VII) by two routes: by the Kizhner reduction of the hydrazone (III) of this piperidone [4], and also by the decomposition with water of 2,5-dimethyl-4-lithiumpiperidine (VI), which is formed by reacting 2,5-dimethyl-4-chloropiperidine (V) with lithium. Chloro derivative (V) was obtained by reacting 2,5-dimethyl-4-piperidol (IV) with thionyl chloride.
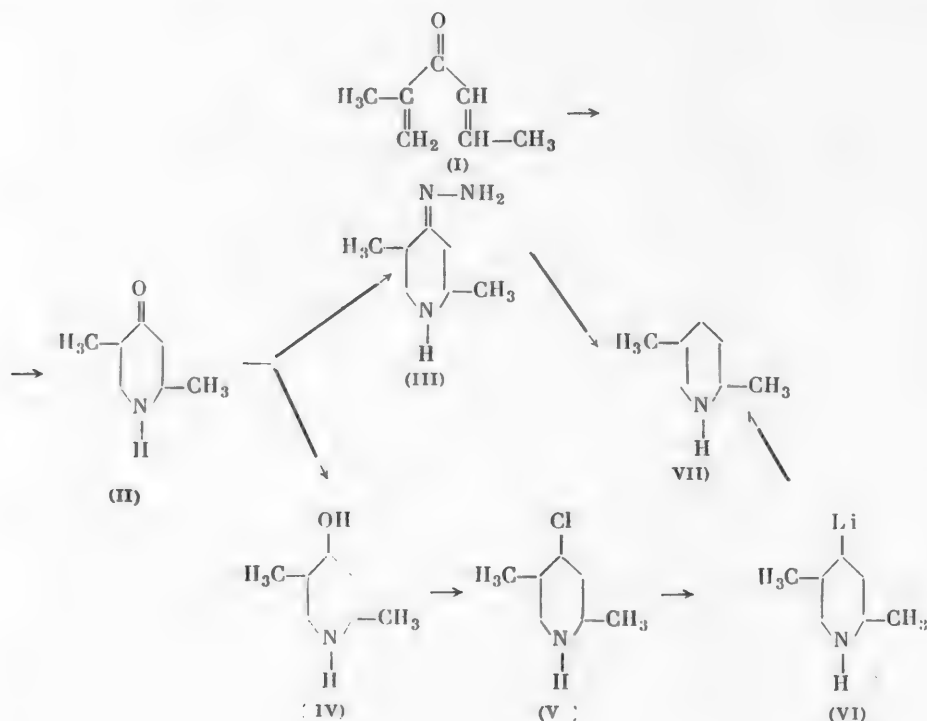
The Mannich condensation of 2,5-dimethylpiperidine (VII) with acetophenone and formaldehyde gave β-(2,5-dimethyl-N-piperidino)ethyl phenyl ketone (VIII), which by reaction with cyclohexylmagnesium chloride was then converted to 1-phenyl-1-cyclohexyl-3-(2,5-dimethyl-N-piperidino)-1-propanol (IX). Based on preliminary pharmacological data (obtained by M. D. Mashkovskii of the All-Union Scientific Research Institute of Pharmaceutical Chemistry), the hydrochloride of this tertiary aminoalcohol shows well-defined antispasmodic action, with an activity somewhat inferior to that of artane.

$$(VII) \rightarrow \quad \text{(VIII)} \quad \rightarrow \quad \text{(IX)}$$
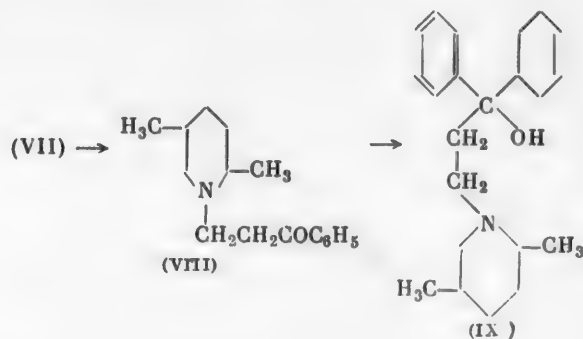
To study the relationship between the antispasmodic activity of tertiary aminoalcohols containing the 2,5-dimethyl-N-piperidino group as the amino radical, and their structure, we synthesized the following compounds: 1,1-diphenyl-3-(2,5-dimethyl-N-piperidino)-1-propanol (X), 1,1-diphenyl-2-(2,5-dimethyl-N-piperidino)-1-propanol (XI), 1,1-dimethyl-3-(2,5-dimethyl-N-piperidino)-1-propanol (XII) and 1-(2,5-dimethyl-N-piperidino)-2-phenyl-2-propanol (XIII).

$$\text{(X)-(XII)} \qquad \text{(XIII)}$$

(X) R = H, R′ = R″ = C₆H₅, n = 1;
(XI) R = CH₃, R′ = R″ = C₆H₅, n = 0;
(XII) R = H, R′ = R″ = CH₃, n = 1.
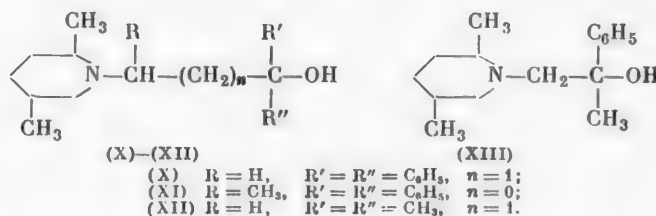
To synthesize these aminoalcohols we used the earlier [4] described ethyl esters of β-(2,5-dimethyl-N-piperidino) propionic and α-(2,5-dimethyl-N-piperidino) propionic acids, and also 1-acetonyl-2,5-dimethylpiperidine and the proper Grignard compounds.

EXPERIMENTAL

2,5-Dimethylpiperidine (VII). To a solution of 20 g of mixed stereoisomeric 2,5-dimethyl-4-piperidols (IV) (b. p. 81-83° at 2 mm) in 100 ml of dry benzene, with ice-water cooling and stirring, was added a solution of 30 ml of thionyl chloride in 40 ml of benzene. After stirring at room temperature for 2 hours, the benzene and excess thionyl chloride were distilled off in vacuo. The residue was dissolved in 100 ml of water, treated with sodium carbonate, and the reaction products extracted with ether. Fractional distillation gave 12 g of 2,5-dimethyl-4-chloropiperidine (V).

B. p. 78-80° (10 mm), d^{20}_4 1.0170, $n^{20}D$ 1.4780, MR 40.80; calc. 41.11.

Found %: N 9.51, 9.51. $C_7H_{14}NCl$. Calculated %: N 9.47.

Picrate, m. p. 219-221° (from alcohol).

Found %: N 14.37, 14.50. $C_{13}H_{17}O_7N_4Cl$. Calculated %: N 14.87.

A mixture of 0.5 g of lithium and 5 g of 2,5-dimethyl-4-chloropiperidine (V) in 100 ml of ether was heated for 8 hours at ether boil. Almost all of the lithium went into solution. The reaction mass was then treated with

50 ml of water, and the ether layer was separated and dried. Fractional distillation gave 2.5 g of 2,5-dimethyl-piperidine (VII) with b. p. 137-138° [4].

β-(2,5-Dimethyl-N-piperidino)ethyl phenyl ketone (VIII). To a solution of 38 g of 2,5-dimethylpiperidine hydrochloride, 9 g of paraformaldehyde, and 0.8 ml of concentrated hydrochloric acid in 90 ml of alcohol, after stirring at 80° for an hour, was added in drops a solution of 31 g of acetophenone in 30 ml of alcohol. The mixture was refluxed for 1 hour and then 7 g of paraformaldehyde was added. This mixture was heated for 9 hours. The solvent was distilled off, and the residue was dissolved in water. The neutral reaction products were extracted with ether, while the remaining water layer was saturated with sodium hydroxide and extracted with ether. Fractional distillation of the reaction products gave 17 g of (VIII) with b. p. 89-93° (4 mm).

Found %: N 5.88, 5.71. $C_{16}H_{23}ON$. Calculated %: N 5.72.

1-Phenyl-1-cyclohexyl-3-(2,5-dimethyl-N-piperidino)-1-propanol (IX). To the cyclohexylmagnesium chloride prepared from 3 g of magnesium and 11 g of cyclohexyl chloride in 100 ml of ether was added, with cooling, 17 g of β-(2,5-dimethyl-N-piperidino)ethyl phenyl ketone (VIII). The reaction mass was heated for 4 hours, after which it was decomposed with 50 ml of water and 18% hydrochloric acid until acid to Congo. The neutral reaction products were extracted with ether. The water layer was saturated with sodium hydroxide, after which it was extracted with ether. Fractional distillation of the products, extracted with the ether, gave 4.5 g of 1-phenyl-1-cyclohexyl-3-(2,5-dimethyl-N-piperidino)-1-propanol (IX) with b. p. 185-190° (2 mm).

Hydrochloride, m. p. 231-233° (from alcohol).

Found %: N 4.07, 4.11. $C_{22}H_{36}ONCl$. Calculated %: N 4.40.

1,1-Diphenyl-3-(2,5-dimethyl-N-piperidino)-1-propanol (X). To the phenylmagnesium bromide prepared from 3 g of magnesium and 19 g of bromobenzene in 50 ml of ether with cooling was added a solution of 10.5 g of ethyl β-(2,5-dimethyl-N-piperidino)propionate in 10 ml of ether. After heating for an hour, the reaction mass was decomposed with 40 ml of saturated ammonium chloride solution. The neutral reaction products were separated by steam distillation, while the residue on cooling deposited 11.2 g of the hydrochloride of (X) with m. p. 243° (from alcohol).

Found %: N 3.98, 3.86. $C_{22}H_{30}ONCl$. Calculated %: N 3.89.

The free base, 1,1-diphenyl-3-(2,5-dimethyl-N-piperidino)-1-propanol, obtained from the hydrochloride, had m. p. 92-93° (from gasoline).

Found %: N 4.43, 4.34. $C_{22}H_{29}ON$. Calculated %: N 4.33.

1,1-Diphenyl-2-(2,5-dimethyl-N-piperidino)-1-propanol (XI) and 1-(2,5-dimethyl-N-piperidino)-2-phenyl-2-propanol (XIII). For reaction we took 2.5 g of magnesium, 18.4 g of bromobenzene, 50 ml of ether and 10 g of ethyl α-(2,5-dimethyl-N-piperidino)propionate (b. p. 84-86° at 2 mm). The reaction was run the same as before. The products of the Grignard synthesis were decomposed with a saturated ammonium chloride solution, the neutral reaction products were removed by steam distillation, and the residue was treated with sodium hydroxide. The organic bases were extracted with ether, and after drying, were vacuum distilled. We obtained 4.5 g of 1,1-diphenyl-2-(2,5-dimethyl-N-piperidino)-1-propanol (XI) with b. p. 195-196° (2 mm).

Hydrochloride, m. p. 184° (decompn.) (from acetone).

Found %: N 3.97, 4.18. $C_{22}H_{30}ONCl$. Calculated %: N 3.89.

The synthesis of aminoalcohol (XIII) was accomplished in a similar manner. For reaction we took 3.6 g of magnesium, 23.2 g of bromobenzene, 60 ml of ether, and 10 g of 1-acetonyl-2,5-dimethylpiperidine. We obtained 3.1 g of 1-(2,5-dimethyl-N-piperidino)-2-phenyl-2-propanol (XIII) with b. p. 156-158° (3 mm).

Hydrochloride, m. p. 174-178° (from alcohol).

Found %: N 4.67, 4.97. $C_{16}H_{26}ONCl$. Calculated %: N 4.94.

1,1-Dimethyl-3-(2,5-dimethyl-N-piperidino)-1-propanol (XII). To the methylmagnesium iodide prepared from 3.7 g of magnesium, 22.7 g of methyl iodide and 30 ml of ether was added 13 g of ethyl β-(2,5-dimethyl-N-piperidino)propionate at 0°. The mixture was heated at ether boil, and then decomposed with 30 ml of water

and 18% hydrochloric acid until acid to Congo. The neutral reaction products were extracted with ether. The water layer was treated with sodium hydroxide, and then extracted with ether. Fractional distillation of the ether extracted products gave 3.7 g of 1,1-dimethyl-3-(2,5-dimethyl-N-piperidino)-1-propanol (XII) with b. p. 92-94° (2 mm).

Hydrochloride, m. p. 86-89° (from acetone).

Found %: N 6.22, 6.12. $C_{12}H_{26}ONCl$. Calculated %: N 5.94.

SUMMARY

The synthesis of some new tertiary aminoalcohols was described, for the synthesis of which we used some of the intermediates in the manufacture of the analgesic, promedol. The hydrochloride of 1-phenyl-1-cyclo-hexyl-3-(2,5-dimethyl-N-piperidino)-1-propanol shows a high antispasmodic activity.

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* Original Russian pagination. See C. B. Translation.

STUDY OF THE MECHANISM OF THE GRIGNARD SYNTHESIS OF ALCOHOLS USING LABELED OXYGEN

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As is known, in the preparation of either alcohols or carboxylic acids by the Grignard method, the last step in the synthesis requires hydrolyzing the carbinolate.*

It is easy to see that two completely different mechanisms are possible here. In preparing alcohols, the hydrolysis of the carbinolate can go either with rupture of the bond between the alkyl group and the oxygen atom (alkyl-oxygen mechanism):

$$R—O—MgHal + HO^*H \rightarrow R—O^*H + Mg(OH)Hal, \qquad (I)$$

or it can go with rupture of the bond between the magnesium and oxygen atoms (metal-oxygen mechanism).

$$R—O—MgHal + HO^*H \rightarrow R—OH + Mg(O^*H)Hal. \qquad (II)$$

Perusal of the literature reveals that the use of isotopes to study the Grignard reaction has received very little attention. Thus, at the present time, only several papers [2] have been published in which exchange with deuterium and tritium to study the hydrolysis of Grignard reagents has been investigated. Some authors [3] have expressed the opinion that it is also possible to effect the exchange of isotopic magnesium between the Grignard reagent and magnesium halides, but an experimental study of isotopic exchange between CH_3MgBr and $Mg^{28}Br_2$ failed to lead to any definite results [4]. Finally, using deuterium, the reducing action of the Grignard reagent was recently studied on the example of the reduction of benzophenone to benzhydrol using isobutylmagnesium bromide [5]. As regards the paths for the shift of the oxygen atom in the Grignard reactions involving the synthesis of alcohols and carboxylic acids, not a single paper was published on this subject.

In this paper an attempt to choose between mechanisms (I) and (II) for the hydrolysis of the carbinolate is discussed. The work was done on the example of synthesizing triphenylcarbinol from benzophenone and phenylmagnesium bromide:

$$(C_6H_5)_2CO + C_6H_5MgBr \longrightarrow (C_6H_5)_2C—OMgBr \longrightarrow$$
$$\longrightarrow (C_6H_5)_3C—OH + Mg(OH)Br.$$
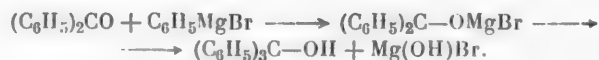
The indicated reactants were chosen for the reason that the triphenylcarbinol formed is, first, very easily isolated from the reaction mixture, and, second, it lends itself easily to analysis for the amount of oxygen isotopes.

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* Nesmeyanov and Sazonova [1] have shown that, contrary to the concepts based on the studies of Hess, Meisenheimer and Pfeiffer, the substances formed in the reaction of aldehydes and ketones with Grignard reagent are not complex addition products, but instead are carbinolates, in harmony with the original viewpoint held by Grignard.

Triphenylcarbinolate. Phenylmagnesium bromide, prepared in the usual manner from 20 g of bromobenzene and 3 g of magnesium, was reacted with 18.2 g of benzophenone in absolute ether medium.

a) The obtained carbinolate, $(C_6H_5)_3COMgBr$, was decomposed with a saturated solution of ammonium chloride in 45 ml of labeled water (1.49 atom % O^{18}).[*] When hydrolysis was complete, the ether layer, containing the triphenylcarbinol, was separated from the water layer.

Recovery of heavy water. The heavy water was distilled from the water layer to complete dryness of the mixture of salts in the distillation flask. After purification there remained 18.9 g (44%) of water with an oxygen-18 content equal to 1.35 atom %.[*]

Isotopic analysis of triphenylcarbinol. The ether was distilled from the ether layer, and then the impurities were removed from the triphenylcarbinol by steam distillation. Further purification was meaningless, since impurities do not interfere with the determination of the heavy oxygen isotope in triphenylcarbinol. A portion of the obtained product was recrystallized from ligroine to give a triphenylcarbinol with constants corresponding to those given in [6]. The dried triphenylcarbinol was dissolved in toluene, and then treated with dry hydrogen chloride in a 100 ml centrifuge tube. Using a pipette, the water that had collected on the bottom of the tube after centrifuging was transferred to a Wurtz flask, and distilled. The collected hydrochloric acid (azeotropic mixture) was neutralized with dry ammonia gas to Methyl orange, after which distillation gave 0.71 ml (40%) of water with an oxygen-18 content equal to 0.254 atom %.

b) The carbinolate was decomposed with 15.03 g of labeled water (1.49 atom % O^{18}). When hydrolysis was complete, the ether layer was separated from the precipitate.

Recovery of heavy water. The precipitate of basic salt was transferred to a distillation flask, and as much of the water as possible was distilled off. After purification there remained 4.58 g (35%) of water with an oxygen-18 content equal to 1.38 atom %.

Isotopic analysis of triphenylcarbinol. The ether was distilled from the ether layer, and the residual triphenylcarbinol was freed of impurities by steam distillation. Using the method described above, we isolated from the triphenylcarbinol 0.57 ml (32%) of water with an oxygen-18 content equal to 0.226 atom %.

It is easy to see that in the case of the alkyl-oxygen mechanism (I), where the O^{18} isotope should be distributed uniformly over the entire oxygen system, since hydroxymagnesium bromide exchanges its oxygen with heavy water very rapidly, both the triphenylcarbinol and the heavy water should contain the same relative excess of O^{18} in their oxygen (96% in Expt. "a", and 89.3% in Expt. "b"). In the case of the metal-oxygen mechanism (II), in both experiments ("a" and "b") the triphenylcarbinol will not contain any excess of oxygen-18, while the heavy water should retain 100% of the relative excess of oxygen-18.

In the table these two possibilities are compared with the actual distribution of the heavy oxygen isotope.

From the data given in the table it can be seen that the actual distribution of oxygen-18 almost exactly coincides with the metal-oxygen mechanism (II). However, the low amount of O^{18} in the heavy water must be explained, since it is possible for the suspicion to arise that here the hydrolysis in some manner actually went according to the alkyl-oxygen mechanism (I), but then the triphenylcarbinol exchanged with the natural water used to steam distill the impurities. Such a possibility is excluded for the following reasons. First, in the studies of Anbar and co-workers it was established that triphenylcarbinol fails completely to suffer oxygen exchange at 100° in alkaline medium [8], while in sulfuric acid medium at 200° it exchanges to the extent of only 13% in 3 hours [9]. In addition, not a single investigator has as yet found an alcohol that is capable of oxygen exchange in neutral aqueous solution [10]. Second, analysis of the oxygen in the heavy water in the case of Expt. "b" demonstrates that a uniform distribution of the O^{18} isotope as a result, for example, of oxygen exchange, or because of the hydrolysis of the carbinolate going in accordance with the alkyl-oxygen mechanism (I), could not have occurred during reaction.

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[*] The water specimens were analyzed by the Brodskii method [7], using a MS-1 mass-spectrometer with a relative accuracy of 2%.

Actually, in Expt. "b" the heavy water contains more O^{18} than it should if uniform distribution had taken place, since in the latter case the relative enrichment would be 89.3%, whereas actually it was equal to 91.5%. This fact rules out completely the possibility of a uniform distribution and conclusively supports the metal-oxygen mechanism (II), since in the case of mechanism (II), a low O^{18} content (91.5% instead of 100% in Expt. "b", and 89% instead of 100% in Expt. "a") in the heavy water can always be explained by its contamination with natural water, whereas in the case of the alkyl-oxygen mechanism (I) it is impossible to explain the high O^{18} content (91.5% instead of 89.3% in Expt. "b") in the heavy water by any means whatsoever. As can be seen, it is possible to derive definite conclusions relative to the studied reaction from an isotopic analysis of the heavy water.

Origin of sample		Content of O^{18} (in atom %), rel. accuracy 2%	Excess of O^{18} (in atom %)	Relative excess of O^{18} (in %)		
				actual distribution	distrib. per mechanism (I)	distrib. per mechanism (II)
Original water		1.49	1.286 ± 0.030	100	100	100
Expt. "a"	oxygen of triphenyl-carbinol	0.254	0.050 ± 0.005	3.9 ± 0.4	96	0
	oxygen of heavy water	1.35	1.146 ± 0.027	89 ± 2	96	100
Expt. "b"	oxygen of triphenylcarbinol	0.226	0.022 ± 0.005	1.7 ± 0.35	89.3	0
	oxygen of heavy water	1.38	1.176 ± 0.028	91.5 ± 2	89.3	100

Nevertheless, it should be mentioned that only an analysis of the triphenylcarbinol itself gives reliable information as to the mechanism of the reaction. A somewhat high oxygen-18 content in the triphenylcarbinol (a relative excess of 3.9 and 1.7% instead of 0% in Expts. "a" and "b", respectively) can be explained, for example, by assuming a slight oxygen exchange during reaction between the labeled water used for the hydrolysis and some other product, or by assuming that the hydrolysis of the carbinolate goes to the extent of 1-2% by the alkyl-oxygen mechanism (I).

And thus, it is finally possible to conclude that the hydrolysis of the carbinolate should go, at least to the extent of 98-99%, with retention of the alkyl-oxygen bond. This result is in complete harmony with study [11], in which, using oxygen-18, it was shown that the hydrolysis of the sodium, magnesium, and aluminum alcoholates of certain primary and secondary alcohols goes with retention of the alkyl-oxygen bond and rupture of the metal-oxygen bond.

It is highly probable that the Grignard syntheses of other alcohols (especially secondary and primary) also proceed with retention of the alkyl-oxygen bond. However, to extend this mechanism to the case of obtaining tertiary alcohols, the alkyl group of which can give highly stable carbonium ions, would, without experimental data, be premature, since there is no assurance that the high stability of the carbonium ion will not cause the metal-oxygen mechanism (II) to be replaced by the alkyl-oxygen mechanism (I).

SUMMARY

Using the preparation of triphenylcarbinol from benzophenone and phenylmagnesium bromide as an example, it was shown that the magnesium carbinolate hydrolyzes with retention of the alkyl-oxygen bond and rupture of the metal-oxygen bond.

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TERTIARY OXONIUM SALTS OF CHROMONES AND THIOCHROMONES

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Kehrmann and Duttenhöfer [1] obtained from 2,6-dimethyl-γ-pyrone and dimethyl sulfate on long standing (4 weeks) the addition product, namely, the methyl methosulfate, which by exchange reaction with potassium iodide was converted to the methiodide (I).
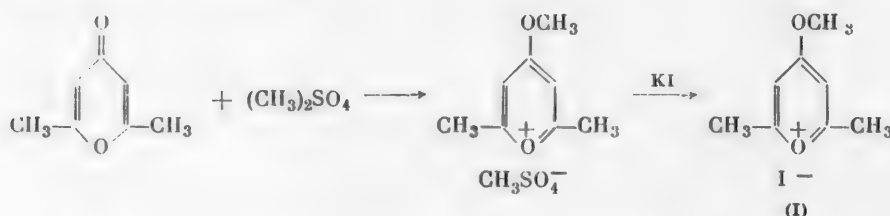
The methiodide proved to be unstable. It gradually dissociated in water solution, and when heated above 100° it decomposed to the dimethylpyrone and methyl iodide. The tertiary oxonium salt could not be obtained by the direct reaction of the dimethylpyrone with either methyl iodide or methyl p-toluenesulfonate. Even with dimethyl sulfate the reaction goes poorly, and the dimethylpyrone sulfate is formed along with the tertiary oxonium salt [2]. All of this is associated with the extremely weak basic properties of the pyrones. The thio-pyrones are stronger bases. When heated with methyl iodide for 1 hour, 2,6-dimethyl-γ-thiopyrone gives the methiodide (II) in quantitative yield [3]. However, it is impossible to recrystallize the methiodide of the dimethylpyrone from either water or alcohol, since it decomposes during recrystallization.

There is no information in the literature on the tertiary oxonium salts of chromone, and the same is also true for the tertiary oxonium salts of flavone. Apparently, these compounds are even weaker bases then γ-pyrone. However, reacting 4-thioflavone with methyl iodide in chloroform solution for 18 hours at room temperature gives the methiodide (III) in excellent yield.
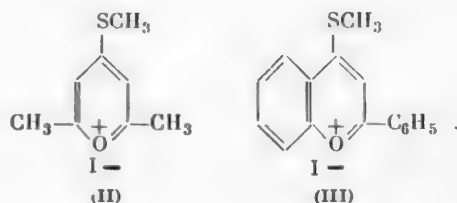
This compound is decomposed completely by boiling water to the flavone and methyl mercaptan [4]. The tertiary oxonium salts of xanthone and thioxanthones are not known.

From this brief survey, it can be seen that the tertiary oxonium salts of γ-pyrone and its derivatives are difficultly available, and for this reason have been studied but slightly. However, the properties of these salts indicate that they are extremely reactive, and can serve as starting materials for a number of diverse transformations.

It has been known for a long time that their reaction with ammonia yields the corresponding pyridines [5, 2, 3]. The 4-methoxy group (or the 4-methylmercapto group) of the tertiary oxonium salts of pyrones will exchange with the radicals of both primary and secondary amines in both the aliphatic and aromatic series, and also with the radicals of thiophenols. The methyl groups are capable of condensing with both aromatic and heterocyclic aldehydes. In the presence of bases, the methyl perchlorate of the dimethylpyrone suffers autocondensation with the formation of an orange dye (IV) [2].

(IV)
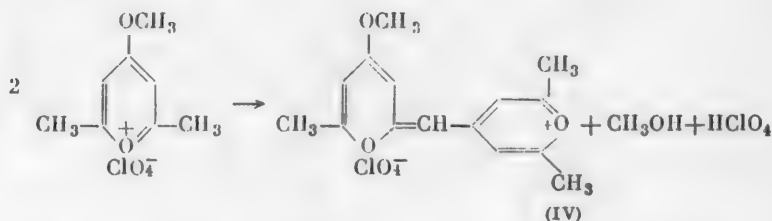
This reaction shows that the methoxy groups are active in respect to nucleophilic reagents, while the methyl groups are active in respect to electrophilic reagents. However, for a more detailed study of the properties and reactions of the tertiary oxonium salts of pyrones, and especially of chromones, it is necessary to have a convenient method for their preparation.

We recently published a method for the preparation of quaternary salts of weak organic bases [6]. The method consists in reacting the weak bases with the esters of nitrobenzenesulfonic acids, which prove to be much stronger alkylating agents than dimethyl sulfate. We now applied this method to chromone and its derivatives. Here, highly favorable results were obtained.

Heating an equimolar mixture of the chromone and the methyl ester of 2,4-dinitrobenzenesulfonic acid at 50° for only 20 minutes gives a quantitative yield of the tertiary oxonium salt (V). When the methyl ester of o-nitrobenzenesulfonic acid is used, it becomes necessary to heat the chromone at the same temperature for 6 hours, or at 100° for 2 hours. Later, it was found that it is possible to obtain the tertiary oxonium salt of the chromone, to be sure, in poorer yield and less pure, also by long heating with dimethyl sulfate.

The isomeric benzochromones form tertiary oxonium salts with the methyl ester of o-nitrobenzenesulfonic acid (VI and VII) more easily than does chromone itself: salt (VI) is obtained in about 90% yield by heating the reactant mixture at 100° for 20 minutes, while salt (VII) is obtained under the same conditions in 95% yield.

$X = o\text{-}NO_2C_6H_4SO_3^-$
$Y = 2,4\text{-}(NO_2)_2C_6H_3SO_3^-$

(V)   (VI)   (VII)
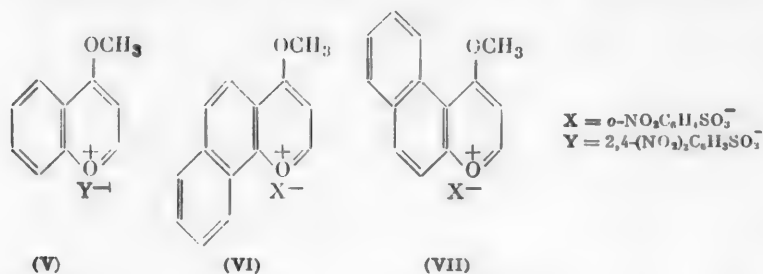
The tertiary oxonium salts of flavone (VIII), 1-thiochromone (IX), 4-thiochromone (X) and 2-methyl-chromone (XI) were obtained in a similar manner.

(VIII)   (IX)   (X)   (XI)
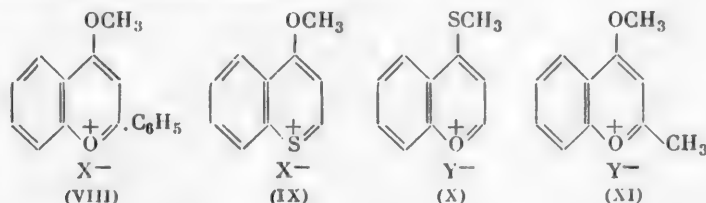
Salt (X) is also obtained as the triiodide by reacting methyl iodide with 4-thiochromone.

The tertiary salt of 2-methylchromone (XI) proved to be the most difficult to obtain. This salt cannot be obtained with either dimethyl sulfate or methyl o-nitrobenzenesulfonate, since it suffers autocondensation to an orange dye (XII)* as soon as it is formed.

(XII)
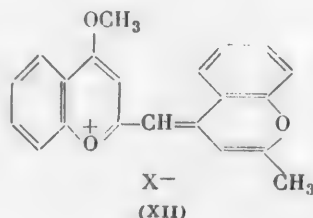
However, using the methyl ester of 2,4-dinitrobenzenesulfonic acid, salt (XI) was obtained in 81% yield.

We were unable to obtain the tertiary oxonium salt of isoflavone with any of the alkylating agents.

All of the enumerated tertiary salts are colorless crystalline compounds with quite high melting points. Due to their lack of stability to water and alcohol, it proved difficult to purify the salts obtained by us. At times, it was possible to recrystallize them with large losses from either acetic acid or acetic anhydride. But in the majority of cases such recrystallization lowered the melting point, rather than raising it. In such cases, we limited ourselves to a thorough washing of the salts with hot toluene and ether. As a rule, we were also unable to replace the anions of the salts (o-nitro- or 2,4-dinitrobenzenesulfonate ions) by other anions, for example, by reacting with sodium iodide or with sodium perchlorate.

Experiments were also run on the preparation of the tertiary oxonium salts of xanthone, thioxanthone, xanthione, and thioxanthione. These experiments proved unsuccessful. Not one of the indicated compounds gives a crystalline product with the methyl ester of either o-nitro- or 2,4-dinitrobenzenesulfonic acid. After heating with the methyl ester of 2,4-dinitrobenzenesulfonic acid for 8 hours at 100°, both xanthione and thioxanthione gave a certain amount of product, which was insoluble in toluene. The reaction product of xanthone dissolved in acetic anhydride with an orange color (λ_{max} 447 mμ), resembling the color of a xanthone solution in concentrated sulfuric acid (λ_{max} 435 mμ), and markedly different from the yellow color of a solution of xanthone itself in acetic anhydride (λ_{max} 405 mμ). The reaction product of thioxanthione with the methyl ester of 2,4-dinitrobenzenesulfonic acid gave in acetic anhydride the same red solution as is obtained in sulfuric acid. All of this leads to the theory that both xanthione and thioxanthione form tertiary oxonium salts, but because of their extreme instability, we were unable to isolate them.

EXPERIMENTAL

Methyl ester of o-nitrobenzenesulfonic acid. Since the preparation of this ester is described in a difficultly available publication [7], we will give the procedure worked out by us.

A solution of 133 g (0.6 mole) of o-nitrobenzenesulfonyl chloride [8] in a mixture of 180 ml of dry benzene and 10 ml of toluene was placed in a 500 ml three-necked flask, fitted with a stirrer, dropping funnel and thermometer. Then to the solution, cooled to 0°, was added from the dropping funnel a solution of sodium methylate, obtained by dissolving 13.8 g (0.6 g-atom) of sodium in 180 ml of methanol. The temperature of the mixture was not permitted to rise above 5° during the addition of the sodium methylate solution. Then the flask contents were transferred to a beaker and stirred with 500 ml of ice water. The precipitate was suction-filtered, washed on the filter with ice water, and dried. We obtained 92 g (70.5%) of pure product, m. p. 60°.

The methyl ester of 2,4-dinitrobenzenesulfonic acid was obtained from the corresponding sulfonyl chloride by the method described by us earlier [9]. 2,4-Dinitrobenzenesulfonyl chloride can be obtained from 2,4-dinitrobenzenesulfonic acid [10] and phosphorus pentachloride, but a more convenient method is that described recently in [11].

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* Soon after this work was completed, a paper appeared in the literature in which this dye is described [31].

To a solution of 200 g of 2,4-dinitrochlorobenzene in 400 ml of alcohol, heated nearly to the boil on the water bath, was added with vigorous stirring a solution of 260 g of crystalline sodium sulfite in 350 ml of water. The dark orange mixture was refluxed with stirring for 4 hours, and then cooled to 0-5°. The yellow crystalline sodium salt of 2,4-dinitrobenzenesulfonic acid was filtered, and washed with 100 ml of 50% alcohol and 50 ml of ether. Recrystallization from 50% alcohol gave 215 g (81%) of pure sodium salt. A portion of this salt (69 g) was dried for 48 hours at 90°, pulverized, and added slowly with stirring to 250 ml of distilled chlorosulfonic acid; then the mixture was heated at 95° for 2 hours. The brown liquid was cooled, and then with vigorous stirring was cautiously poured over 800 g of cracked ice. The cream-colored precipitate was suction filtered, washed well with water, and dried in a vacuum oven. Yield 48 g (71%), m. p. 101-102°. If the unrecrystallized sodium salt is taken, the yield is 63%, m. p. 100-101°.

Chromone was obtained from o-hydroxyacetophenone and ethyl formate [12]. The condensation product of these two compounds, 2-hydroxy-ω-formylacetophenone, without being recrystallized, was heated on the water bath with dilute sulfuric acid for 30 minutes. Then the solution was treated with carbon, and the solution was filtered hot. The product obtained on cooling was filtered, washed on the filter with water, and dried. When recrystallized from water it contained 1 molecule of crystallization water, which escapes when the compound is allowed to stand over sulfuric acid in a desiccator. The yield based on o-hydroacetophenone was 52%.

o-Hydroxyacetophenone was obtained in 37% yield by reacting phenyl acetate with aluminum chloride [13]. The yield in this synthesis drops if the temperature is kept below 200°. This is the reason for Meisenheimer and Chou [14] being unable to obtain more than a 25% yield of o-hydroxyacetophenone. A recent statement made by some Indian authors [15] that reducing the amount of aluminum chloride permits increasing the yield of o-hydroxyacetophenone to 80% was checked by us and found to be erroneous.

Tertiary oxonium salts of chromone. 4-Methoxybenzopyrylium 2,4-dinitrobenzenesulfonate (V) was obtained by heating a mixture of 0.005 g-mole of chromone and 0.005 g-mole of methyl 2,4-dinitrobenzene-sulfonate at 50° for 20 minutes. The solid product was washed with hot toluene and dry ether. Yield quantitative, m. p. 206°.

Found %: N 6.87, 6.91. $C_{16}H_{12}O_9N_2S$. Calculated %: N 6.86.

Recrystallization from acetic acid lowered the melting point to 201°.

4-Methoxybenzopyrylium o-nitrobenzenesulfonate was obtained by heating a mixture of 0.10 g-mole of chromone and 0.11 g-mole of methyl o-nitrobenzenesulfonate at 50° for 6 hours, or at 100° for 2 hours. After washing with toluene and ether the yield was 85.5%. The salt is hygroscopic, is soluble in water, suffering hydrolysis with the separation of chromone, and is also decomposed by alcohol.

4-Methoxybenzopyrylium methyl methosulfate was obtained by heating 0.005 g-mole of chromone with 0.006 g-mole of dimethyl sulfate for 10 hours at 50°. A hygroscopic viscous mass was obtained after washing with toluene and ether, yield 44%.

1:4-α,β-Naphthopyrone was obtained from 2-aceto-1-naphthol [16] and ethyl formate through 2-hydroxy-ω-formylacetonaphthone. The latter was cyclized by heating with sulfuric acid [17].

4-Methoxy-1:4-α,β-naphthopyrylium o-nitrobenzenesulfonate (VI) was obtained by heating a mixture of 0.1 g-mole of 1:4-α,β-naphthopyrone and 0.1 g-mole of methyl o-nitrobenzenesulfonate at 100° for 20 minutes. The product was triturated with dry benzene, and then washed with acetone and ether. Yield 87.5%. Recrystallization from acetic anhydride gave the compound as needle crystals with m. p. 153°.

Found %: S 7.59, 7.70. $C_{20}H_{15}O_7NS$. Calculated %: S 7.75.

1:4-β,α-Naphthopyrone [18] was obtained in the same manner as its isomer. A mixture of 5 g of 1-aceto-2-naphthol and 15 ml of ethyl formate in 50 ml of dry ether was refluxed for 2 hours with 3 g of comminuted sodium. The obtained yellow solid was dissolved in water, and the impurities were extracted with ether. Acidification with sulfuric acid gave 5.6 g (97%) of 3-hydroxy-ω-formylacetonaphthol; recrystallization from alcohol gave the compound as colorless needles with m. p. 158°.

Found %: C 72.97, 72.98; H 4.57, 4.75. $C_{13}H_{10}O_3$. Calculated %: C 72.90; H 4.67

A solution of 5 g of the above compound in 50 ml of anhydrous alcohol was treated with 10 ml of concentrated sulfuric acid, and the mixture refluxed for 3 hours. The solution was treated with carbon, and after filtering, was diluted with ice water. The yield of the naphthopyrone was 4 g (85%); recrystallization from a mixture of alcohol and benzene gave the compound as needles with m. p. 101° (literature [18]; m. p. 103°).

4-Methoxy-β, α-naphthopyrylium o-nitrobenzenesulfonate (VII) was obtained under the same conditions as the salt of its isomer. The yield was quantitative. The salt is not hygroscopic, and after recrystallization from acetic acid it has m. p. 132°.

Found %: S 7.58, 7.66. $C_{20}H_{15}O_7NS$. Calculated %: S 7.75.

Flavone was obtained from o-hydroxyacetophenone and benzoyl chloride [19].

4-Methoxyflavylium o-nitrobenzenesulfonate (VIII) was obtained by heating a mixture of 0.05 mole of flavone and 0.05 mole of methyl o-nitrobenzenesulfonate at 50° for 8 hours. The product was triturated with anhydrous benzene, separated, and washed with benzene and dry ether. White powder, yield 92%. Recrystallization from acetic anhydride gave the compound as prisms with m. p. 185°.

Addition of an aqueous solution of sodium perchlorate to a methanol solution of the salt gave 4-methoxyflavylium perchlorate as colorless needles with m. p. 223° (from acetic anhydride).

Found %: Cl 10.78, 10.58. $C_{16}H_{12}O_6Cl$. Calculated %: Cl 10.58.

1-Thiochromone was obtained from thiochromanone and phosphorus pentachloride [20]. Yield 60%, m. p. 78°. Thiochromanone was prepared from thiophenol and β-bromopropionic acid [21], yield of β-phenylmercaptopropionic acid 97%, yield of thiochromanone 73%, m. p. 29-30°.

4-Methoxy-1-thiobenzopyrylium o-nitrobenzenesulfonate (IX) was obtained in the same manner as the corresponding chromone salt. The compound, obtained as yellow crystals, was not purified.

4-Thiochromone [22]. A mixture of 18 g of pulverized phosphorus pentasulfide and 5.84 g of chromone in 250 ml of xylene was refluxed for 30 minutes. The solution was filtered, and the xylene was vacuum distilled. The residue was extracted with boiling benzene, and the benzene solution was chromatographed on aluminum oxide. The lower light-cream colored zone after recrystallization from gasoline gave 3.4 g (52.4%) of pure thiochromone. Long red needles, m. p. 93°. 4-Thiochromone is readily soluble in benzene, ether and chloroform, and moderately soluble in methyl and ethyl alcohols. Addition of a drop of water to a light-red alcohol solution of the compound gives an orange color, while the solution in concentrated sulfuric acid has a pale yellow color.

Tertiary oxonium salts of 4-thiochromone. 4-Methylmercaptobenzopyrylium 2,4-dinitrobenzenesulfonate (X) was obtained by heating a mixture of 0.0025 mole of 4-thiochromone and 0.0025 mole of methyl 2,4-dinitrobenzenesulfonate at 60° for 10 minutes. The product was triturated with anhydrous benzene, separated, and washed with the same solvent. White powder, yield 79%. After recrystallization from glacial acetic acid, m. p. 184°.

Found %: S 14.69, 14.94. $C_{16}H_{12}O_8N_2S$. Calculated %: S 15.09.

4-Methylmercaptobenzopyrylium triiodide was obtained in the same manner as the preceding salt from 0.0025 mole of 4-thiochromone and 0.01 mole of methyl iodide. Yield 28%. Recrystallization from glacial acetic acid gave the compound as needles with m. p. 165°.

Found %: I 68.27, 68.40; S 5.73, 5.90. $C_{10}H_9OSI_3$. Calculated %: I 68.28; S 5.74.

Methylchromone was obtained from o-hydroxyacetophenone and ethyl acetate through 2-acetylacetophenol [23]. Needles, m. p. 73°.

2-Methyl-4-methoxybenzopyrylium 2,4-dinitrobenzenesulfonate (XI) was obtained in the same manner as the chromone salt. Yield 81%, m. p. 192-193°.

Found %: N 6.94, 7.13. $C_{17}H_{14}O_9N_2S$. Calculated %: N 6.64.

Xanthone was obtained from phenyl salicylate [24].

Thioxanthone was obtained from anthranilic acid and thiophenol through phenylthiosalicylic acid [25]. Yield 77%, m. p. 209-210°.

Thioxanthione was obtained from thioxanthone by heating with phosphorus pentasulfide in xylene [26]. M. p. 176°, yield 58%. Heating thioxanthone with phosphorus pentasulfide without solvent gave only a 5% yield of thioxanthione [27].

Isoflavone. Joshi and Venkataraman [28] gave unsatisfactory directions for the preparation of isoflavone, and therefore we give our own method. A mixture of 2 g of o-hydroxyphenyl benzyl ketone [29] and 20 ml of ethyl formate was added to 1 g of comminuted sodium in a flask fitted with a reflux condenser. When reaction was ended, the flask was heated for 3 hours at 55-65°, and then the mixture was cooled, followed by stirring with ice and ether. The water layer was neutralized with acetic acid, and the resulting product filtered and then dissolved in 20 ml of concentrated sulfuric acid. After 1 hour the solution was poured over ice, and the precipitate was filtered, washed with water, and recrystallized from alcohol. Yield of isoflavone 1.2 g (58%), m. p. 136° (literature [30]; m. p. 136°).

SUMMARY

By heating chromone, two isomeric naphthopyrones, flavone, 1-thiochromone, 4-thiochromone and 2-methyl-chromone with the methyl esters of o-nitro- and 2,4-dinitrobenzenesulfonic acids we obtained the tertiary oxonium salts of these weak bases, previously unknown. Both xanthione and thioxanthione when heated for a long time with the methyl ester of 2,4-dinitrobenzenesulfonic acid gave unstable compounds, which we were unable to isolate in the pure state. Xanthone and isoflavone do not react with the methyl ester of 2,4-dinitrobenzenesulfonic acid.

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INTRODUCTION OF SUBSTITUENTS IN THE BENZENE RING OF INDOLE

V. SYNTHESIS OF KETONES OF THE INDOLE SERIES [1]

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Very little study has been devoted to indoles containing an acyl group in the benzene ring. When indole is treated with acylating agents the acyl group enters the pyrrole ring, and only in the case where the 1, 2, and 3 positions of the indole are occupied, does it become possible to acylate the indole in the benzene ring. Thus, 1-acetyl-2,3-dimethylindole reacts with acetyl chloride under Friedel-Crafts conditions to yield 1,6-diacetyl-2,3-dimethylindole [2]. N. N. Suvorov and co-workers [3] state that 2,3-dimethylindole, acylated in the benzene ring, is formed when the Fischer reaction with the asymmetrical methylphenylhydrazone of methyl ethyl ketone is run in acetic anhydride medium.

In this paper we describe the preparation of 5-acylated indoles by the dehydrogenation of the corresponding indolines. The behavior of indolines in the Friedel-Crafts reaction has hardly been studied earlier. However, mention should be made of the paper by Woodward and co-workers [4], in which the following ketone of the indoline series (I) was obtained as an intermediate in the synthesis of lysergic acid.
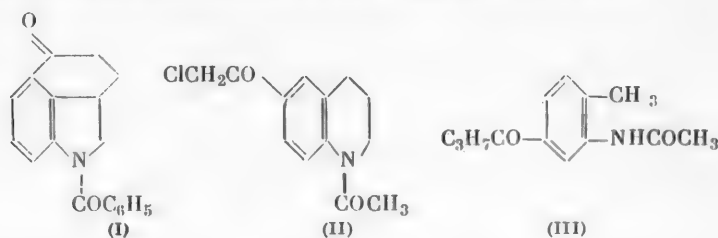
However, the Friedel-Crafts acylation of analogs close to indoline, namely, of tetrahydroquinoline and o-toluidine, has been studied in some detail. 1-Acetyltetrahydroquinoline does not react with acetyl chloride in the presence of aluminum chloride, but does react with chloroacetyl chloride to give 1-acetyl-6-chloro-acetyltetrahydroquinoline (II) [5]. When the Friedel-Crafts reaction is run with o-acetotoluidide [6], the acyl group enters para to the alkyl group (III). Consequently, the formation of both the 5- and 6-acyl derivatives could be expected in the case of 1-acetylindoline. We found that the Friedel-Crafts acylation of 1-acetylindolines led to the acyl group entering the 5-position of the indole ring.

We used 1-acetylindoline (IV) and 1-acetyl-2-methylindoline (V) as the starting materials in our work.
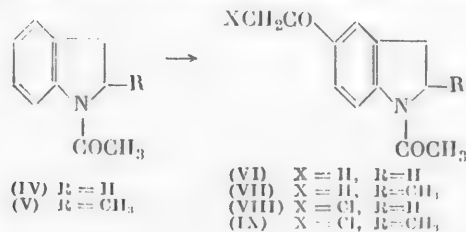
Both (IV) and (V) were reacted with acetyl chloride and with chloroacetyl chloride. In our work, we used the method described by Kunckell for the acylation of acetanilide [7] (the reaction is run in carbon disulfide medium, using aluminum chloride as the catalyst).

The following compounds were obtained in high yields: 1,5-diacetylindoline (VI), 1,5-diacetyl-2-methylindoline (VII), 1-acetyl-5-chloroacetylindoline (VIII) and 1-acetyl-5-chloroacetyl-2-methylindoline (IX). Besides (VIII), the reaction of 1-acetylindoline (IV) with chloroacetyl chloride and aluminum chloride yields a small amount of another substance, which, apparently, is an isomer of (VIII); this substance is possibly 1-acetyl-7-chloroacetylindoline (X).

It is possible to obtain the same yields of the 1,5-diacylindolines by running the acylation reaction without solvent. This method is more satisfactory, since it does not require using the flammable and toxic carbon disulfide.
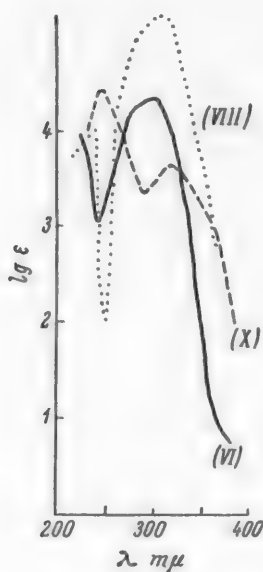
Fig. 1. Ultraviolet absorption spectra of 1,5-diacylindolines.
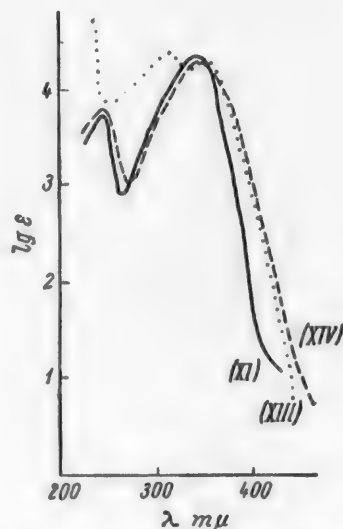
Fig. 2. Ultraviolet absorption spectra of 5-acylindolines. The spectrum of (XII) coincides with the spectrum of (XI).

When the 1,5-diacyl derivatives (VI) - (IX) were refluxed with dilute hydrochloric acid they were converted to the corresponding 5-acylindolines (XI) - (XIV) in yields ranging from 80 to 90%.

(XI)   X = H, R = H
(XII)   X = H, R = CH₃
(XIII) X = Cl, R = H
(XIV)   X = Cl, R = CH₃

(XV)   X = H, R = H
(XVI)   X = H, R = CH₃
(XVII) X = Cl, R = H
(XVIII) X = Cl, R = CH₃
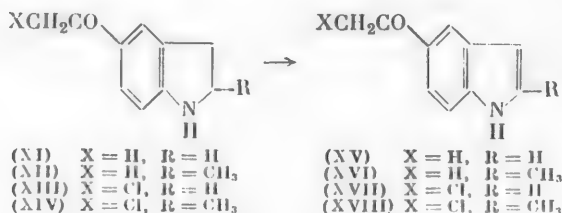
The 5-acylindolines were dehydrogenated to the corresponding indoles (XV) - (XVIII) by refluxing with chloranil in xylene solution (yields 50-60%). Below we give the over-all yields for the indoles obtained by us, based on the corresponding Bz-unsubstituted indole (indole or α-methylindole → indoline → 1-acetylindoline → 1,5-diacylindoline → 5-acylindoline → 5-acylindole). The yield of indoline from indole is 95% [8], and that of 2-methylindoline from 2-methylindole is 74% [9]; the acylation on the nitrogen is quantitative.

Yield of (XV) — 51%, (XVI) — 36%, (XVII) — 34%, (XVIII) — 27%; (XI), (XII), and (XVI) were characterized as the oximes; in the case of (XV) we prepared the semicarbazone.

The obtained chloroacetylindolines (XIII), (XIV) are skin irritants and lachrymators, and also cause sneezing. These properties are less pronounced for the chloromethylindolyl ketones (XVII) and (XVIII), and are practically absent for the N-acylated chloroacetylindolines (VIII), (IX), and (X).

The UV-absorption spectra of the obtained indolines are similar in nature, and differ from the UV-absorption spectra of the obtained indoles. The spectra of the ketones in the indole series coincide (see Figs. 1, 2, and 3).*

We proved the structure of the obtained ketones in the following manner: the oxime of 5-acetylindoline (XIX) was subjected to Beckmann rearrangement, and here 5-acetamido-1-acetylindoline (XX) was obtained in quantitative yield, proving to be identical with authentic 5-acetamido-1-acetylindoline [1].

Fig. 3. Ultraviolet absorption spectra of 5-acylindoles. 1) (XV), 2) (XVI), 3) (XVII), 4) (XVIII).
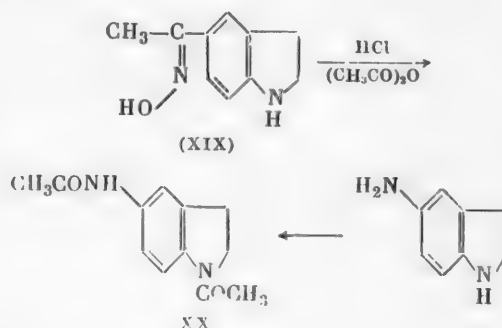
To run the Beckmann rearrangement we used the procedure described for the oxime of 5-acetyl-8-hydroxyquinoline [10]. 5-Acetylindoline (XI) was reduced by the Clemmensen procedure to 5-ethylindoline (XXI).

(XI) X = H
(XIII) X = Cl

(XXI)
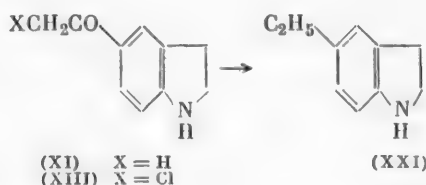
To show that the reaction of 1-acetylindoline (IV) with chloroacetyl chloride and aluminum chloride gives 5-chloroacetyl-1-acetylindoline (VIII) as the predominant isomer, this compound, after hydrolysis with hydrochloric acid, was also reduced by the Clemmensen procedure. The acetyl derivative of the reduction product proved to be identical with authentic 5-ethyl-1-acetylindoline.

EXPERIMENTAL

1,5-Diacetylindoline (VI). a) To a solution of 16.1 g of 1-acetylindoline (IV) in 50 ml of purified, dry carbon disulfide [11] was added 10 ml of acetyl chloride, and then with stirring, 40 g of anhydrous aluminum chloride was added in portions. Evolution of heat was observed, as well as a vigorous evolution of hydrogen

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* A SF-4 spectrophotometer was used to take the spectra. Methyl alcohol was used as the solvent.

chloride. The reaction mixture was heated for several hours on the water bath at 50°. The upper carbon disulfide layer was decanted, while the dark viscous mass was poured over ice, and the obtained crystals were filtered. We obtained 20.7 g of diacetylindoline (VI), which is a quantitative yield. The constants and analysis data are given in Table 1.

TABLE 1
1,5-Diacylindolines

Com-pound	Yield (in %) (a)	Yield (in %) (b)	Melting point	Empirical formula	Found (%)[*] C	Found (%)[*] H	Found (%)[*] N	UV-spectrum λ_{max} (mμ)
(VI)	100	100	146—147° (from heptane	$C_{12}H_{13}O_2N$	70.77, 70.67 (70.99)	6.63, 6.40 (6.45)	—	310
(VII)	85	81	96.5—97 (from heptane	$C_{13}H_{15}O_2N$	71.74, 71.75 (71.86)	7.08, 7.18 (6.96)	6.33, 6.52 (6.45)	
(IX)	75.4	—	149.5—150 (decomp) (from methanol)	$C_{13}H_{14}O_2NCl$	61.96, 61.96 (62.03)	5.62, 5.67 (5.61)	—	
(VIII)	95	70	250—251 (decomp) (from dioxane	$C_{12}H_{12}O_2NCl$	60.68, 60.59 (60.63)	5.09, 5.01 (5.09)	5.97, 5.97 (5.89)	245, 320

b) A mixture of 5 g of 1-acetylindoline (IV) and 12 g of aluminum chloride was ground in a mortar, and 10 ml of acetyl chloride was added gradually during the grinding. The evolution of heat was observed, and also a copious evolution of hydrogen chloride. After several minutes the reaction mixture was transferred to a flask and heated for 30 minutes on the water bath, after which it was poured over ice. The obtained crystals were filtered. We obtained 6.3 g of the diacetylindoline.

The other 1,5-diacylindolines were prepared in a similar manner. They are all yellow crystalline compounds. The yields, obtained running the reaction in carbon disulfide (a) and without solvent (b), and also the constants and analysis data, are given in Table 1.

The following method was used to separate (VIII) and (X): the crystals obtained from the reaction were placed in an extractor and extracted with octane. (VIII) is insoluble in octane, and only (X) is extracted. The solution on cooling deposited 1-acetyl-7-chloroacetylindoline (X). The yield ranged from 5 to 10%. Changing the reaction conditions (ratio of the reactants, order of mixing the reaction components, etc.) was practically without effect on the yield. M. p. 134.5-135° (from octane). White crystalline compound.

Found%: C 60.67, 60.45; H 5.00, 4.97. $C_{12}H_{12}O_2NCl$. Calculated %: C 60.63; H 5.09.

UV-absorption spectrum: λ_{max} 248, 320 mμ, log ϵ 4.40, 3.60.

Preparation of 5-acetylindoline (XI). A charge of 2.8 g of 1,5-diacetylindoline (VI) was placed in dilute hydrochloric acid (1:1) and boiled until complete solution was obtained. The dark red solution was filtered, and then neutralized with sodium bicarbonate. We obtained 1.9 g of yellow crystals. The other 5-acylindolines were obtained in a similar manner. All of them are yellow crystalline compounds, and were purified by recrystallization from octane.

The analysis data, constants and yields of the obtained compounds are given in Table 2.

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[*] The calculated values are given in parentheses.

TABLE 2
5-Acylindolines

Compound and yield (in %)	Melting point	Empirical formula	Found (%)[*]			UV-spectrum	
			C	H	N	λ_{max} (mμ)	$lg\ \varepsilon_{max}$
(XI), 86.5	70.5—71°	$C_{10}H_{11}ON$	73.97, 74.05 (74.51)	6.73, 6.81 (6.88)	—	241, 340	3.71, 4.30
(XII), 88	88—89	$C_{11}H_{13}ON$	—	—	8.63 (7.99)	241, 342	3.79, 4.53
(XIII), 90	96—96.5	$C_{10}H_{10}ONCl$	61.59 (61.37)	5.38 (5.15)	6.87, 7.03 (7.16)	315, 345	4.36, 4.29
(XIV), 88	107—107.5	$C_{11}H_{12}ONCl$	—	—	6.53, 6.55 (6.78)	245, 346	3.78, 4.28

[*] The calculated values are given in parentheses.

5-Acetylindoline oxime (XIX) was obtained by heating 4.3 g of (XI), 5 g of hydroxylamine hydrochloride and 8 g of sodium acetate in aqueous alcohol solution. The reaction mixture was poured into water, followed by extraction of the oxime with ether. We obtained 4.6 g (98%) of the oxime as pale yellow crystals with m. p. 142-143° (from aqueous alcohol).

Found %: C 68.63, 68.67; H 7.07, 7.01. $C_{10}H_{12}ON_2$. Calculated %: C 68.16; H 6.86.

5-Acetyl-2-methylindoline oxime was obtained by a similar procedure in 86% yield. M. p. 114-115.5° (from aqueous alcohol).

Found %: C 69.64, 69.88; H 7.70, 7.78; N 14.57, 14.47. $C_{11}H_{14}ON_2$. Calculated %: C 69.45; H 7.42; N 14.72.

5-Acetylindole (XV). A solution of 0.8 g of acylindoline (XI) and 1.2 g of chloranil in xylene was refluxed for two hours, cooled, shaken with 20% caustic solution, filtered, and the xylene layer washed in succession with 20% caustic solution, water, dilute hydrochloric acid and water. The xylene was vacuum distilled. After some time the residual oil crystallized. We obtained 0.5 g of acetylindole (XV).

The oxime of 5-acetylindole (XV) was obtained by refluxing a solution of 0.5 g of 5-acetylindole (XV), 0.5 g of hydroxylamine hydrochloride and 1.5 g of sodium acetate in aqueous alcohol solution for 1 hour. White crystals of the oxime were obtained on cooling. M. p. 163.5-164.5° (from alcohol).

Found %: N 13.83, 13.96. $C_{11}H_{12}ON_2$. Calculated %: N 13.71.

The semicarbazone of (XV) was obtained by refluxing an aqueous alcohol solution of (XV), semicarbazide and sodium acetate. M. p. 200.5-201° (from water).

Found %: N 26.03, 25.87. $C_{11}H_{12}ON_4$. Calculated %: N 25.90.

The other ketones in the indole series were obtained in a similar manner (see Table 3). All of the obtained indoles are white crystalline compounds, rapidly turning pink in the air.

Beckmann rearrangement of 5-acetylindoline oxime. With cooling, a stream of dry hydrogen chloride was passed for 20 minutes into a solution of 1.8 g of 5-acetylindoline oxime (XIX) in a mixture of 17 ml of aqueous acetic acid and 7 ml of acetic anhydride. The reaction mixture was heated in a sealed ampul on the water bath for 3 hours. Crystals deposited on cooling, which were filtered. We obtained 2.3 g (quantitative yield) of 5-acetamido-1-acetylindoline (XX). White crystalline compound. M. p. 212-212.5° (from water).

Found %: C 65.75, 65.74; H 6.48, 6.48. $C_{12}H_{14}O_2N_2$. Calculated %: C 66.02; H 6.46.

According to [1], 5-acetamido-1-acetylindoline has m. p. 211-212.5°. The mixed melting point of the rearrangement product with authentic 5-acetamido-1-acetylindoline was not depressed.

The melting point given in the literature for 6-acetamido-1-acetylindoline is 269-271°. The mixed melting point of the Beckmann rearrangement product with authentic 6-acetamido-1-acetylindoline was depressed sharply.

TABLE 3
Acetylindoles

Compound and yield (in %)	Melting point	Empirical formula	Found (%) *			UV-spectrum	
			C	H	N	λ_{max} (mμ)	lg ε_{max}
(XV), 63	94—95° (from heptane)	$C_{10}H_9ON$	75.31, 75.34 (75.43)	6.00, 5.92 (5.70)	—	247, 295	4.26, 3.92
(XVI), 65	140.5—141 (from aqueous alcohol)	$C_{11}H_{11}ON$	76.72, 76.95 (76.72)	5.78, 5.92 (5.86)	—	259, 298	4.69, 4.05
(XVII), 43	139—140 (decomp) (from octane)	$C_{10}H_8ONCl$			6.80, 7.00 (7.18)	250, 307	4.91, 4.23
(XVIII), 56	153—155 (decomp) (from octane)	$C_{11}H_{10}ONCl$	63.86, 63.98 (63.80)	4.72, 4.93 (4.86)	—	255, 302	4.57, 4.13

* The calculated values are given in parentheses.

5-Ethylindoline (XXI). A mixture of 24.3 g of 1,5-diacetylindoline and 100 ml of hydrochloric acid (1:1) was refluxed until solution was obtained, after which the reaction mixture was treated with granulated zinc amalgam (30 g) and another 200 ml of concentrated hydrochloric acid. The mixture was refluxed for 6 hours. The solution was decanted from the granulated zinc, then treated with concentrated caustic solution until strongly alkaline, and the ethylindoline removed by steam distillation. The product was extracted with ether, and the ether solution was dried over potassium carbonate. The ether was distilled off, followed by the vacuum distillation of (XXI). We obtained 3 g (12.5 %) of a pale yellow oil with an odor resembling that of aniline.

B. p. 110-111° (7 mm), d^{20}_4 1.0220, $n^{20}D$ 1.5724, MR_D 47.43. $C_{10}H_{13}N$ F3. Calculated: 47.38.

Found %: C 81.38, 81.19; H 8.71, 8.74. $C_{10}H_{13}N$. Calculated %: C 81.59; H 8.90.

1-Acetyl-5-ethylindoline was obtained by boiling (XXI) with acetic anhydride. White crystals. M. p. 116-116.3°.

Found %: N 7.50, 7.60. $C_{12}H_{15}ON$. Calculated %: N 7.42.

Preparation of 1-acetyl-5-ethylindoline from acetylindoline (VIII). A mixture of 4.65 g of acetylindoline (VIII) and concentrated hydrochloric acid was refluxed until complete solution was obtained, after which the reaction mixture was treated with granulated zinc amalgam, and after refluxing for 5 hours, the reaction mixture was worked up in the same manner as in the preceding experiment. After distilling off the ether, the residual ethylindoline was treated with acetic anhydride, the mixture heated to the boil, and then poured into water. We obtained 0.7 g (19.5%) of 1-acetyl-5-ethylindoline. M. p. 117.5-117.8°. The mixed melting point with the 1-acetyl-5-ethylindoline, obtained in the preceding experiment, was not depressed.

SUMMARY

1. A number of 1,5-diacylindolines were obtained in high yields by reacting either 1-acetylindoline or 1-acetyl-2-methylindoline with either acetyl chloride or chloroacetyl chloride in the presence of aluminum chloride. Hydrolysis of the compounds obtained in this manner gave 5-acetylindoline, 5-chloroacetylindoline, 5-acetyl-2-methylindoline, and 5-chloroacetyl-2-methylindoline.

2. Refluxing of the corresponding 5-acylindolines with chloranil in xylene solution gave 5-acetylindole, 5-chloroacetylindole, 5-acetyl-2-methylindoline, and 5-chloroacetyl-3-methylindole.

3. The Beckmann rearrangement of 5-acetylindole oxime gave 5-acetamido-1-acetylindoline, which served to prove the structure of the obtained ketones in the indole and indoline series.

4. The Clemmensen reduction of either 5-acetylindoline or 5-chloroacetylindoline gave 5-ethylindoline. It was shown that the Friedel-Crafts reaction of 1-acetylindoline with chloroacetyl chloride yields a mixture of 1-acetyl-5-chloroacetylindoline and another isomer in a 9:1 ratio.

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HYDROGENATION OF UNSATURATED COMPOUNDS IN THE PRESENCE OF COLLOIDAL PALLADIUM

XIII. HYDROGENATION OF CARBOCYCLIC ENYNE HYDROCARBONS

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In previous papers we discussed the results of our investigations on the hydrogenation of vinylacetylene, alkyl- and phenylacetylenes [1]. In other papers in which one of us participated, the results of studying the hydrogenation of vinylalkyl- and alkenylacetylenes were described [2]. A study of the hydrogenation of hydrocarbons of the carbocyclic series with a conjugated enyne system on colloidal palladium seemed of interest.

With this in mind, we investigated the hydrogenation of 1-ethynyl-1-cyclopentene (I), 1-ethynyl-1-cyclohexene (II), 1-phenyl-3-buten-1-yne (III),and 4-phenyl-3-buten-1-yne (IV). Here it proved that hydrocarbons (I) and (II), similar to other vinylacetylenes [2], do not add six atoms of hydrogen. Hydrocarbons (III) and (IV) hydrogenate completely. Hydrocarbons (I), (II), and (IV) add the first two atoms of hydrogen at a nearly constant rate, then the reaction rate increases sharply, and after the addition of four atoms of hydrogen it again decreases markedly (Fig. 1). The earlier studied hydrocarbons with a terminal acetylene group also behaved in a similar manner [2].
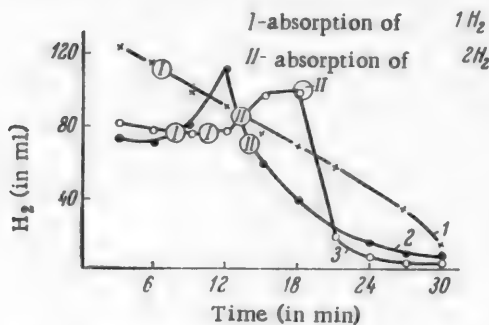
Fig. 1. Hydrogenation rate curves. 1) 1-Phenyl-3-buten-1-yne; 2) 4-phenyl-3-buten-1-yne; 3) 1-ethynyl-1-cyclopentene. (The curve for 1-ethynyl-1-cyclohexene is not shown, since it nearly coincides with curve 3).

The rate with which hydrogen adds to hydrocarbon (III), having the acetylene bond in the middle of the chain, decreases steadily (Fig. 1). The addition of the first two hydrogen atoms could go in three directions: to the acetylene bond (1,2-addition), to the ethylene bond (3,4-addition), and in the 1,4-position with the formation of allene hydrocarbons. Also not excluded is the possibility of the originally formed dienes or acetylenes subsequently suffering transition into olefins.

The decision as to the structure of the obtained hydrogenation products was based on the infrared spectra, the analysis data for the triple bond using silver nitrate [3], the yield of adduct with α-naphthoquinone, and the physical constants. In not one of the investigated cases, the same as in earlier studies, were we able to show the formation of allene hydrocarbons. Analysis of the hydrogenation products of hydrocarbon (I), using silver nitrate, revealed that acetylenic hydrocarbon was present to the extent of 4.7%, while only traces of it were found in the hydrogenation products of hydrocarbon (II). The infrared spectrum of the hydrogenation product of hydrocarbon (I) showed frequencies for the terminal acetylene grouping (weak intensity) at about 2120 and 3300 cm^{-1}. These frequencies are absent in the hydrogenation products of hydrocarbon (II) (Fig. 2).

The spectra of the hydrogenation products of hydrocarbons (I) and (II) show frequencies for the conjugated 1,3-diene grouping.

Condensation of the hydrogenation product of hydrocarbon (I) with α-naphthoquinone gave 1,2-trimethylene-1,4,11,12-tetrahydro-9,10-anthraquinone, which confirms the principal formation of 1-vinyl-1-cyclopentene in the hydrogenation of hydrocarbon (I). Condensation of the hydrogenation product of hydrocarbon (II) with α-naphthoquinone gave 1,2-tetramethylene-1,4,11,12-tetrahydro-9,10-anthraquinone, which when oxidized with air in alcoholic caustic solution gave golden yellow crystals of 1,2-tetramethylene-9,10-anthraquinone [4]. Consequently, the hydrogenation product of hydrocarbon (II) is 1-vinyl-1-cyclohexene.
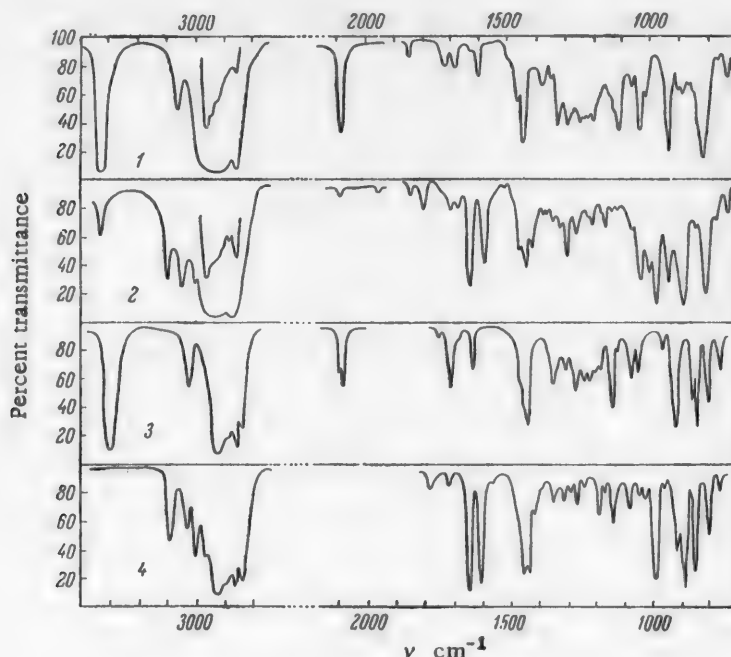
Fig. 2. Infrared spectra. 1) 1-Ethynyl-1-cyclopentene; 2) hydrogenation product of 1-ethynyl-1-cyclopentene; 3) 1-ethynyl-1-cyclohexene; 4) hydrogenation product of 1-ethynyl-1-cyclohexene.

The hydrogenation product of hydrocarbon (III) was distilled through a Widmer column into three fractions. From an analysis of the infrared spectra (Fig. 3), it was established that all three fractions contain a small amount of the starting compound (frequencies 2216 and 2184 cm^{-1}), in which connection its amount increases with increase in the boiling point of the fraction. All of the fractions contain compounds with the grouping $-CH=CH-$ (frequency 968 cm^{-1}). Their amount also increases with increase in the boiling point of the fraction. The increase in the amount of compounds with a conjugated double bond (the intensity of the frequency at 1604 cm^{-1} increases) also shows the same relationship to the boiling point.

Both an analysis of the spectra and a comparison of the physical constants of the hydrogenation products, the original hydrocarbon (III), sym-phenylethylethylene and phenylbutadiene, testify to the fact that the hydrogenation of hydrocarbon (III), the same as in the earlier examined cases of hydrogenating disubstituted acetylenes [2], begins with the addition of hydrogen to the triple bond, followed by transition of the thus formed phenyldiene to the phenylolefin. We were unable to separate the obtained mixture of hydrocarbons into the pure components.

The hydrogenation of hydrocarbon (IV) went much more selectively at the triple bond to give principally the phenylbutadiene, which could be judged by the appearance of only a slight turbidity when the reaction mixture was tested with ammoniacal silver oxide solution, by a weak intensity of the frequencies at 2120 and 3300 cm^{-1} in the infrared spectrum [*] (Fig. 4), corresponding to a terminal acetylene grouping, and by comparing the physical constants of the hydrogenation product with those of phenylbutadiene.

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[*] We wish to thank T. V. Yakovleva for assistance in interpreting the infrared spectra.
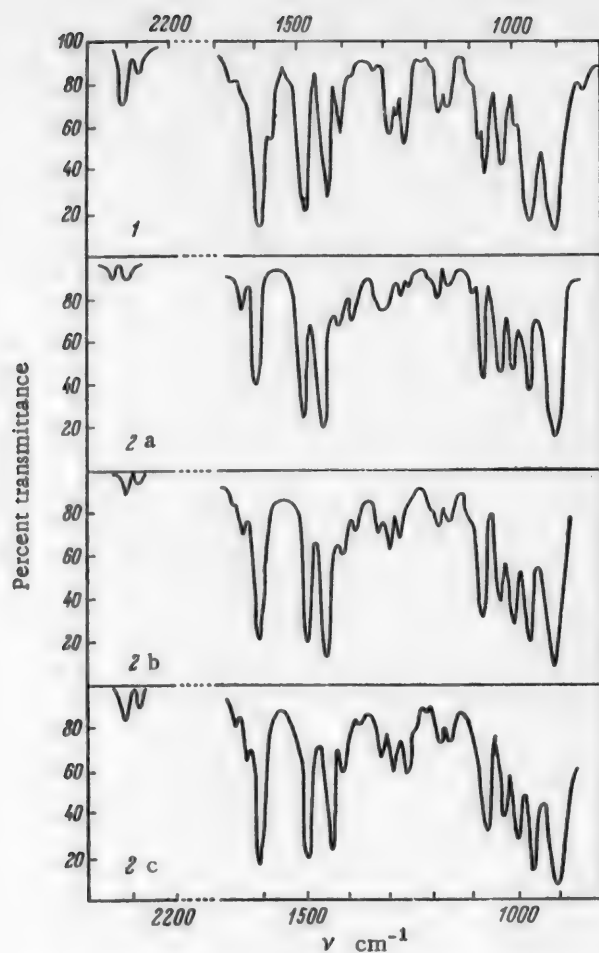
Fig. 3. Infrared spectra. 1) 1-Phenyl-3-buten-1-yne;
2) hydrogenation products of 1-phenyl-3-buten-1-yne;
fraction 68-73° (2a); fraction 73-78° (2b); fraction 78-81° (2c).
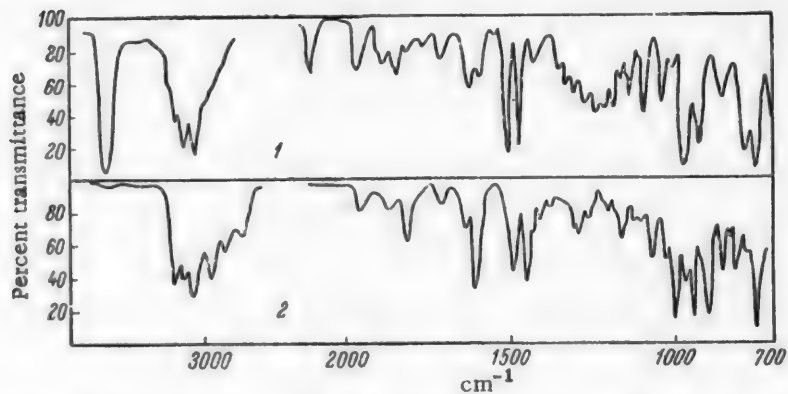
Fig. 4. Infrared spectra. 1) 4-Phenyl-3-buten-1-yne; 2) hydrogenation
product of 4-phenyl-3-buten-1-yne.

As a result, it was shown that carbocyclic enyne hydrocarbons with a terminal acetylene group, like 1-ethynyl-1-cyclopentene, 1-ethynyl-1-cyclohexene and 4-phenyl-3-buten-1-yne, the same as their aliphatic analogs [1, 2], show strictly selective hydrogenation at the triple bond when hydrogenated in the presence of colloidal palladium to yield the corresponding hydrocarbon with a conjugated system of double bonds. The addition of hydrogen to 1-phenyl-3-buten-1-yne, being a disubstituted acetylene, also begins at the triple bond to yield the dienic hydrocarbon, but in this case the hydrogenation does not stop at this stage: to a certain degree the dienic hydrocarbon suffers further hydrogenation to the corresponding olefin. An explanation of this phenomenon has already been given in an earlier paper in which one of us participated [2].

EXPERIMENTAL

The hydrocarbons 1-ethynyl-1-cyclopentene and 1-ethynyl-1-cyclohexene were obtained from the corresponding alcohols: 1-ethynyl-1-cyclopentanol [b. p. 63-64° (14-15 mm), d^{20}_4 0.9750, n^{20}D 1.4736] and 1-ethynyl-1-cyclohexanol [b. p. 70-73° (13-14 mm), d^{20}_4 0.9758, n^{20}D 1.4818]. The constants of the alcohols agreed with those given in [5, 6].

By dehydration using phosphorus oxychloride [7], the alcohols were converted to 1-ethynyl-1-cyclopentene [b. p. 57-59° (100 mm), d^{20}_4 0.8596, n^{20}D 1.4891] and 1-ethynyl-1-cyclohexene [b. p. 47-49° (20 mm), d^{20}_4 0.9032, n^{20}D 1.4956], the constants of which agreed with those given in [7].

1-Phenyl-3-buten-1-yne was obtained from the alcohol, 1-phenyl-1-butyn-4-ol. The latter was synthesized from phenylacetylenemagnesium bromide and ethylene oxide [8], and its constants agreed with those given in [8]: b. p. 124-125° (5 mm), d^{20}_4 1.0748 and n^{20}D 1.5739. The alcohol was dehydrated in vacuo over alkali.

A charge of 6 g of KOH pellets, 10 g of 1-phenyl-1-butyn-4-ol and a small amount of neozone (to prevent polymerization of the hydrocarbon) was placed in a 50 ml Favorskii flask. Since the reaction goes with heat evolution and strong frothing, external heating at a vacuum of 80-60 mm has to be done very slowly at the start. Then the heat was increased, the vacuum was reduced, and the fraction with b. p. 60-75° (6-7 mm) was collected. After drying and a second fractionation in vacuo we obtained a mobile colorless liquid with b. p. 96° (20 mm), d^{20}_4 0.9484 and n^{20}D 1.6008, which agrees with the literature data for 1-phenyl-3-buten-1-yne [9]. Despite this, the infrared spectrum of this product showed the presence of about 8-10% of a compound with a terminal acetylene grouping (frequencies 2120 and 3300 cm^{-1}). The presence of such a compound could have been due to an acetylenic rearrangement of the Favorskii type. The possibility that a small amount of the starting phenyl-acetylene remained in the alcohol itself is also not excluded. The impurities with a terminal acetylene grouping were removed as the silver derivatives.
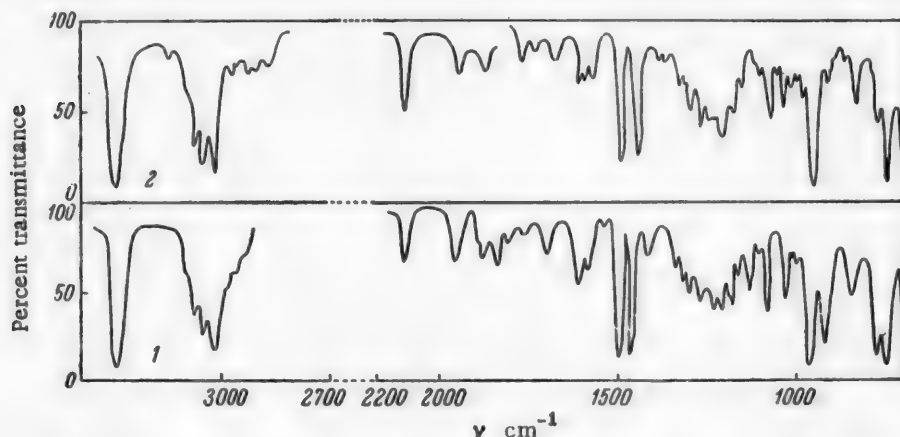
Fig. 5. Infrared spectra. 1) 4-Phenyl-3-buten-1-yne, obtained through phenyl-diazonium chloride; 2) 4-phenyl-3-buten-1-yne, obtained through the alcohol by the S. N. Reformatskii reaction.

TABLE 1

Exhaustive Hydrogenation of Hydrocarbons [*]

Hydrocarbon	Amount (in g)	Calc. amt. of hydrogen (in ml)	Pressure (in mm)	Amount of hydrogen absorbed (in ml) in the time (in min)														
				3	6	9	12	15	18	21	24	27	30	33	60	90	120	160
1-Ethynyl-1-cyclopentene	0.93	736	763	81	158	225	301	400	498	516	522	527	530	533	552	565	572 [**]	—
1-Ethynyl-1-cyclohexene	1.06	740	764	85	165	235	328	430	528	538	545	549	553	556	568	574	576 [**]	—
1-Phenyl-3-buten-1-yne	1.29	748	759	122	237	333	422	496	564	623	680	716	730	736	758	764	765	—
4-Phenyl-3-buten-1-yne	0.94	533	767	74	145	225	338	397	430	453	465	471	476	479	496	503	507	510

* The charge was about 0.01 mole of hydrocarbon, 3 ml of colloidal palladium solution (6 mg of Pd) and 30 ml of methanol, and the temperature was 20°.

** An attempt in a number of experiments to achieve complete hydrogen addition (6H) by adding a new portion of catalyst proved unsuccessful.

We attempted to obtain 4-phenyl-3-buten-1-yne from phenyldiazonium chloride and vinylacetylene [10]. However, although the physical constants coincided with those given in [10], the compound was found to contain about 3% of chlorine, and the amount of compounds with a triple bond [3] did not exceed 83%. The infrared spectrum (Fig. 5) showed intense frequencies for the allene grouping (1960 cm^{-1}). This problem became the subject of a separate investigation [11]. The hydrocarbon needed for the work was synthesized through the alcohol, which was obtained by the S. N. Reformatskii reaction from propargyl bromide and benzaldehyde [12], and here it proved that, due to partial acetylene-allene rearrangement, the obtained mixture analyzed approximately 80% acetylene and 20% allene alcohols. Propargyl bromide was obtained from propargyl alcohol that had been dried well over sodium sulfate (the alcohol had b. p. 112-113°, d^{20}_4 0.9718, $n^{20}D$ 1.4308) and phosphorus tribromide [13]. The obtained propargyl bromide (yield 72%) had b. p. 37-38° (140 mm), d^{19}_4 1.5782, $n^{19}D$ 1.4940. From 40 g of propargyl bromide and 35 g of freshly distilled benzaldehyde we obtained 20.3 g of the alcohol with b. p. 96-97° (3.5 mm), d^{20}_4 1.0498 and $n^{20}D$ 1.5486.

Treatment of 18.5 g of the above alcohol with thionyl chloride in the presence of pyridine gave the corresponding chloride with b. p. 78-79° (3 mm), d^{20}_4 0.9050 and $n^{20}D$ 1.5550 (yield 52%). Judging from the infrared spectrum, the obtained chloride, 4-chloro-4-phenyl-1-butyne, contains very little if any of the allene chloride. The cleavage of hydrogen chloride from 7.3 g of the chloride, employing alcoholic caustic solution, gave 3.4 g of the hydrocarbon 4-phenyl-3-buten-1-yne, practically free (based on the infrared spectrum, Fig. 5) of the allene derivative, and with b. p. 65-67° (3 mm), d^{20}_4 0.9784 and $n^{20}D$ 1.6047. Based on analysis with silver nitrate, the amount of triple bond was 94.6%.

The hydrogenations were run in the earlier described apparatus, using the same sample of colloidal palladium (2 mg of Pd in 1 ml of solution) in all cases. The activity of the catalyst was checked on tetramethyl-butynediol. The hydrogen was obtained by

the electrolysis of caustic. The hydrogenation was run at room temperature and atmospheric pressure, with mechanical shaking of the flask at a rate of 120 times per minute. The results of the exhaustive hydrogenation are given in Table 1.

The results of hydrogenating the hydrocarbons using a 1:1 mole ratio of hydrocarbon to hydrogen are summarized in Table 2.

TABLE 2

Hydrogenation of Hydrocarbons Using a 1:1 Mole Ratio of Hydrocarbon to Hydrogen

Hydrocarbon	Amt. of hydrocarbon (in g)	Amt. of catalyst (in ml)	Amt. of methanol (in ml)	Amt. of hydrogen absorbed (in ml)	Temp.	Pressure (in mm)	Time (in min)
1-Ethynyl-1-cyclopentene	12.04	10	140	3194	19°	762	42.5
1-Ethynyl-1-cyclohexene	8.8	7	50	2054	21	760	47.0
1-Phenyl-3-buten-1-yne	18.99	15	150 *	3578	21	779	23.0
4-Phenyl-3-buten-1-yne	2.93	1.5	30 *	561	20	762	63.0

* A small amount of neozone was added to prevent possible polymerization.

After running the hydrogenation, the reaction mass, with external cooling, was diluted with cold water, and then steam distilled. The distillate was saturated with calcium chloride, and the separated hydrocarbon was dried over fused calcium chloride, and then distilled. The constants of the hydrocarbons, isolated from the hydrogenation of (I) and (II), are given in Table 3.

TABLE 3

Hydrocarbon	Yield (in %)	Boiling point (pressure in mm)	$d_4^{2?}$	n_D^{20}	Amt. of compounds with triple bond
1-Vinyl-1-cyclopentene	88.2	111—112°(14)	0.8296	1.4849	4.72%
1-Vinyl-1-cyclohexene	86.3	143—144 (14) 44—45 (22)	0.8512	1.4953	Traces

Condensation of the hydrogenation products with α-naphthoquinone. a) A mixture of 0.94 g of the hydrogenation product of hydrocarbon (I) and 1.58 g of α-naphthoquinone was heated in a sealed tube for 3 hours on the boiling water bath. The obtained precipitate was washed with methanol. We obtained 2.1 g of a white crystalline product, which after recrystallization from anhydrous alcohol had m. p. 119-120° [14].

b) The reaction of 0.3025 g of the hydrogenation product of hydrocarbon (II) with 0.4455 g of α-naphthoquinone, in the same manner as described above, gave 0.6134 g of a white powderlike compound with m. p. 95°. Recrystallization from anhydrous alcohol gave the compound as coarse white needles with m. p. 101-102°, corresponding to 1,2-tetramethylene-1,4,11,12-tetrahydro-9,10-anthraquinone [4, 14]. A stream of air was sucked through a purple suspension of the compound in alcoholic caustic. The obtained red precipitate was washed with alcoholic caustic solution, dried, and recrystallized from glacial acetic acid. We obtained 0.54 g of the tetramethyleneanthraquinone as golden yellow crystals with m. p. 152-153° [4].

The hydrogenation product of 1-phenyl-3-buten-1-yne (16.5 g, 86.8%) was distilled through a Widmer column at 12 mm. The following fractions were obtained: 1st, 68-73°, 5.66 g, d_4^{20} 0.9034, $n^{20}D$ 1.5439; 2nd, 73-78°, 5.69 g, d_4^{20} 0.9198, $n^{20}D$ 1.5705; 3rd, 78-81°, 4.68 g, d_4^{20} 0.9361, $n^{20}D$ 1.5885; residue 0.46 g.

Below we give the literature data for a number of hydrocarbons, the formation of which [15-18] could be expected under our conditions:

		Boiling point (pressure in mm)	Density	Refractive index
1.	$C_6H_5CH=CH-CH=CH_2$	73—74° (10)	d_4^{20} 0.9286	n_D^{20} 1.6073
2.	$C_6H_5CH=CH-CH_2-CH_3$	78 (12), 70—71 (8)	d_4^{18} 0.9124	n_D^{18} 1.5414
3.	$C_6H_5CH_2-CH=CH-CH_3$	70 (12), 76 (18)	d_4^{15} 0.8857	n_D^{15} 1.5109
4.	$C_6H_5CH_2CH_2-CH_2-CH_3$	180 (760)	$d_4^{13.5}$ 0.875	$n_D^{13.5}$ 1.4940
5.	$C_6H_5CH_2CH_2CH=CH_2$	72—73 (13)	d_4^{20} 0.8831	n_D^{20} 1.5059
6.	$C_6H_5-C\equiv C-CH_2-CH_3$	87—90 (18)	d^{21} 0.9230	n_D^{18} 1.5370

A comparison of the obtained physical constants with those given in the literature, and a study of the infrared spectra, make it possible to conclude that hydrocarbons 3, 4, and 5 are absent in the obtained fractions. Analysis of the infrared spectra supports the fact that all of the fractions contain hydrocarbons 1, 2 , and the original.

We isolated 2.4 g (82%) of the product from the hydrogenation of 4-phenyl-3-buten-1-yne, which after additional purification in the presence of neozone had the constants: b. p. 75-76° (11 mm), d^{20}_4 0.9282, $n^{20}D$ 1.6012, corresponding to those for 1-phenyl-1,3-butadiene. Both the analysis of the infrared spectrum of this compound and the absence of a precipitate when treated with ammoniacal silver oxide solution are in harmony with this conclusion.

SUMMARY

1. The hydrogenation of hydrocarbons of the carbocyclic series with a conjugated enyne system, on colloidal palladium, in methanol solution, was studied.

2. It was established that under the indicated conditions the hydrocarbons 1-ethynyl-1-cyclopentene and 1-ethynyl-1-cyclohexene do not add six atoms of hydrogen, whereas both 1-phenyl-3-buten-1-yne and 4-phenyl-3-buten-1-yne hydrogenate completely.

3. The investigated hydrocarbons with a terminal acetylene group show strictly selective hydrogenation of the triple bond. The hydrogenation of 1-phenyl-3-buten-1-yne, being a disubstituted acetylene, also begins at the triple bond with the formation of the dienic hydrocarbon, but then the dienic hydrocarbon partially hydrogenates further to the olefin. As a result of this, the hydrogenation of 1-phenyl-3-buten-1-yne yields a mixture of hydrocarbons composed of the original, the diene, and the olefin.

4. The hydrogenation rate of hydrocarbons with a terminal acetylene group increases sharply after the first two hydrogen atoms have added and then it decreases again. The rate with which hydrogen adds to the hydrocarbon, 1-phenyl-3-buten-1-yne, shows a steady decrease.

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STEROIDS

V. THE SELECTIVE REDUCTION OF PREGNANE-3,11,20-TRIONE WITH SODIUM BOROHYDRIDE IN PYRIDINE

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In our synthesis of cortisone from solasodine [1] we used the method of selective reduction of the carbonyl group in the 3 position of pregnane-3,11,20-trione (I) by means of sodium borohydride in pyridine [2]. The thus obtained pregnane-3α-ol-11,20-dione (II), with constants corresponding to those given in the literature, was converted to pregnane-3α,17α-diol-11,20-dione (V) by a modification of the scheme proposed by Gallagher and Hogg [3, 4]:
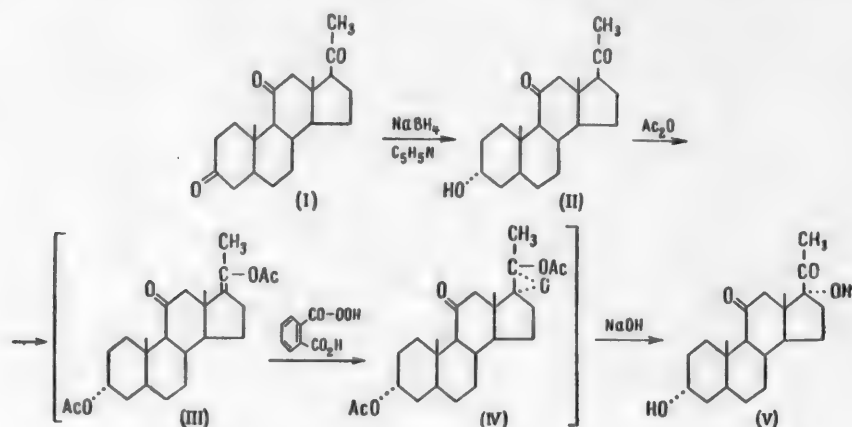
In working up the benzene mother liquor from the recrystallization of the crude pregnane-3α,17α-diol-11,20-dione, we isolated a crystalline compound (VI) with m. p. 225-226°, in its composition corresponding to the empirical formula $C_{23}H_{36}O_4$. The infrared spectrum of this compound showed bands at 3475 cm^{-1} (hydroxyl group), 1686 cm^{-1} (carbonyl group) and 1728 cm^{-1} (acetyl group). Refluxing of (VI) with an aqueous methanol solution of sodium hydroxide gave the previously known pregnane-3α, 20 β-diol-11-one (VII), the structure of which was confirmed by preparing the diacetate, and by oxidation to pregnane-3,11,20-trione (I). Taking into consideration the ease with which an acetyl group in the 3 position is hydrolyzed, and the fact that the infrared spectrum shows a band at 3475 cm^{-1}, characteristic for a hydroxyl group in the 3 position, we assigned the structure of pregnane-3 α, 20 β-diol-11-one 20-acetate to compound (VI). *

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* The spectroscopic studies of the obtained compounds were done under the supervision of Yu. N. Sheinker, to whom we express our sincere thanks.

Since in the course of converting pregnan-3α-ol-11,20-dione (II) to pregnane-3α,17α-diol-11,20-dione (V), including enolization of the keto group in position 20, oxidation of the $\Delta^{17,20}$ double bond with perphthalic acid, and hydrolysis of the acetyl groups with dilute alkali in the cold, it is impossible for acetate (VI) to be formed, we postulated that the latter is obtained due to the presence of pregnane-3α,20β-diol-11-one as impurity in the starting (II). Utilizing the poor solubility of pregnane-3α,20β-diol-11-one in benzene (1:450), we established that the pregnan-3α-ol-11,20-dione with m. p. 170-170.5° and $[\alpha]^{20}$D +102.6° (1% solution in chloroform), obtained by the reduction of pregnane-3,11,20-trione with sodium borohydride in pyridine, contains about 11% of the dihydroxy derivative (VII). It is fortuitous that this impurity exerts very little effect on the constants of pregnan-3α-ol-11,20-dione, since the completely pure specimen has m. p. 175-175.5° and $[\alpha]^{20}$D +113.3° (1% solution in chloroform).

It was stated in the literature [2] that whereas the reduction of pregnane-3,11,20-trione with sodium borohydride in alcohol gives pregnane-3α,20β-diol-11-one (VII), the use of pyridine as the solvent gives only pregnan-3α-ol-11,20-dione (II). It was shown by us that this strictly selective reduction does not exist. Even when pregnane-3,11,20-trione is reduced with sodium borohydride in pyridine, using a distinct deficiency of the reducing agent, a certain amount of pregnane-3α-20β-diol-11-one is always formed as by-product:
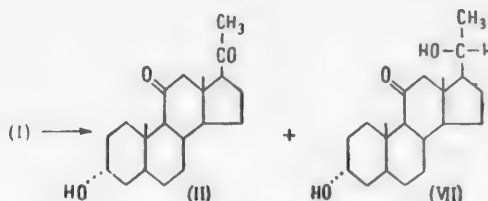
The amount of (VII) increases markedly if the reduction is run at a temperature above 20°.

A convenient method was developed by us for the preparation of pure pregnan-3α-ol-11,20-dione in about 70% yield.

EXPERIMENTAL

Pregnane-3α,17α-diol 11,20-dione (V) and pregnane-3α,20β-diol-11-one 20-acetate (VI). A mixture of 10 g of pregnan-3α-ol-11,20-dione [2], having the constants given in the literature (m. p. 170-170.5°, $[\alpha]^{20}$D + 102.6°), and 35 ml of acetic anhydride was refluxed for 30 minutes. After distilling off the acetic anhydride in vacuo, the residue was dissolved in a mixture of 212.8 ml of dry toluene and 20.1 ml of acetic anhydride, containing 0.401 g of sulfosalicylic acid. Then the reaction mixture was refluxed for 12 hours, with removal of the acetic acid formed in the reaction by azeotropic distillation. The crude enol acetate (III), obtained by decomposing the excess acetic anhydride with ice water and removal of the solvents by vacuum distillation, was dissolved in 20 ml of chloroform, and then oxidized at room temperature with an ether solution of perphthalic acid (19.3 g of acid in 91 ml of ether). Removal of the excess perphthalic acid by washing with cold dilute alkali solution, followed by vacuum distillation of the solvents at a temperature not exceeding 30°, gave oxide (IV). The latter, without purification, was saponified with an aqueous methanol solution of sodium hydroxide (261 ml of 0.73 N solution) for 55 minutes at room temperature. The methanol solution was neutralized with dilute (1:4) hydrochloric acid, and the reaction product was extracted well with chloroform. The chloroform solution was washed with water, dried over magnesium sulfate, the solvent vacuum distilled, and the residue refluxed for 30 minutes with 200 ml of benzene, after which it was allowed to stand for 2 days at room temperature to crystallize. The obtained precipitate was filtered, washed with benzene and ether, and dried in a vacuum oven at 50°. The yield of pregnane-3α,17α-diol-11,20-dione was 6.3 g (59.7%).

M. p. 200.5-202°, $[\alpha]^{20}$D + 66.5° (1% solution in acetone). IR-spectrum: 1700 and 3272 cm^{-1}.

The benzene mother liquor was boiled with activated carbon, filtered, and the filtrate concentrated to $^1/_3$ of the original volume. After a day the precipitate was filtered, washed with benzene and ether, and dried in vacuo. We obtained 1.6 g of a second crop with m. p. 182-205°. The latter was boiled with acetone (1:13).

The precipitate obtained (1.5 g) on cooling was filtered and dried. M. p. 220-225°. After recrystallization from acetone, anhydrous alcohol and dichloroethane, pregnane-3α,20β-diol-11-one 20-acetate has the following constants:

M. p. 225-226°, $[\alpha]^{20}$D + 51.7° (1% solution in chloroform). IR-spectrum: 1728, 1686, and 3475 cm^{-1}.

Found %: C 73.47, 73.21; H 9.62, 9.57. $C_{23}H_{36}O_4$. Calculated %: C 73.36; H 9.65.

Pregnane-3α,20β-diol-11-one (VII). Pregnane-3α,20β-diol-11-one 20-acetate (VI) (0.5 g) was refluxed for 1 hour with a solution of 0.7 g of NaOH in a mixture of 13 ml of water and 44 ml of methanol. The reaction mixture was cooled to 0°, neutralized with dilute hydrochloric acid (1 : 4), and the reaction product extracted with chloroform. The chloroform solution was washed with water, dried over anhydrous sodium sulfate, and the solvent distilled off in vacuo. The residue (0.46 g) was boiled with 40 parts of benzene, the solution cooled, and the product filtered. We obtained 0.42 g of pregnane-3α, 20β-diol-11-one.

M. p. 233-234° (from ethyl acetate). IR-spectrum: 3272, 1700 cm^{-1}.

Literature data: M. p. 236-238° [5], 231-232° [2].

Found %: C 75.32, 75.16; H 10.11, 10.05. $C_{21}H_{34}O_3$. Calculated %: C 75.40; H 10.25.

The compound was characterized by preparing the diacetyl derivative.

Pregnane-3α,20β-diol-11-one diacetate. A solution of 1 g of pregnane-3α,20β-diol-11-one in 2.5 ml of dry pyridine was treated with 1 ml of acetic anhydride, and the mixture allowed to stand at room temperature for 18 hours. Then the reaction mass was added dropwise at 0° to 150 ml of water, containing 2.8 ml of concentrated hydrochloric acid. The obtained precipitate was filtered, washed with water, and dried in a vacuum desiccator. We obtained 1.2 g of pregnane-3α, 20β-diol-11-one diacetate.

M. p. 158.5-159.5° (from alcohol), $[\alpha]^{20}$D + 76.3° (1% solution in acetone).

Literature data: M. p. 160.5-161°, $[\alpha]^{25}$D + 81° (acetone) [5]; m. p. 157-159°, $[\alpha]^{20}$D + 79° (acetone) [2].

Found %: C 71.91; H 9.23. $C_{25}H_{38}O_5$. Calculated %: C 71.74; H 9.15.

Oxidation of pregnane-3α,20β-diol-11-one (VII). To a solution of 5 g of diol (VII) in 100 ml of acetic acid was added at 18-19°, in 3 minutes, a previously warmed to 30° chromic mixture, obtained from 3.11 g of potassium dichromate, 3 ml of concentrated H_2SO_4 and 15 ml of water. The temperature of the reaction mixture rose to 38°, and after running the reaction for 30 minutes the reaction mixture was added in drops to a 2% sulfuric acid solution, cooled to 0-2°. The precipitate was filtered, washed with dilute sulfuric acid and water, and dried in a vacuum desiccator over sulfuric acid. We obtained 4.46 g (90%) of pregnane-3,11,20-trione with m. p. 155.5-156.5°, $[\alpha]^{20}$D + 119.3° (1% solution in acetone), identical with the compound obtained by the oxidation of pregnan-11α-ol-3,20-dione.

Reduction of pregnane-3,11,20-trione (I) with sodium borohydride. a) Pregnan-3α-ol-11,20-dione (II) (preparative method). To a solution of 50 g of pregnan-3,11,20-trione in 100 ml of pyridine was added 18 ml of water, and then with vigorous stirring, a solution of 7.2 g of sodium borohydride (analyzing 87% pure) in 300 ml of pyridine was added dropwise in 7 hours, maintaining the temperature of the reaction mixture at 18-20°. Then the stirring at this temperature was continued for another 2 hours, after which the reaction mixture was poured slowly into dilute hydrochloric acid (575 ml of concentrated HCl in 5.2 liters of water) and the stirring continued for an hour. The precipitate was filtered, washed with 5% hydrochloric acid and water, and dried in a vacuum oven at 50°. We obtained 41 g of technical product. To remove the pregnane-3α,20β-diol-11-one impurity, the technical product was refluxed for 30 minutes with 820 ml of benzene, and then allowed to stand at room temperature for 24 hours. The diol was filtered, washed with 5-7 ml of benzene, and dried. We obtained 3.5 g (6.9%) of pregnane-3α, 20β-diol-11-one, the oxidation of which made it possible to recover 2.95 g of the starting pregnanetrione.

The benzene mother liquor was evaporated in vacuo to dryness, and the residue was recrystallized from butyl acetate. We obtained 33.3 g of pregnan-3α-ol-11,20-dione with m. p. 173-173.5°, $[\alpha]^{20}$D + 113° (1% solution in chloroform). Taking into account the recovered triketone, the total yield of the compound was 70.4%.

b) Effect of the amount of sodium borohydride on the course of the reduction. To a solution of 3 g of pregnane-3,11,20-trione in a mixture of 28 ml of pyridine and 1.2 ml of water was added 0.4 g of sodium borohydride (87% pure, and experimentally found to be the optimum amount of reducing agent), and the solution was allowed to stand at room temperature for 7 hours. Then the reaction mixture was poured into 300 ml of 5% hydrochloric acid at 0°. The reaction product was extracted with chloroform. The chloroform layer was washed with water, 10% sodium bicarbonate solution, and again with water. After drying over anhydrous magnesium sulfate, the solvent was removed by vacuum distillation. The residue was refluxed for 30 minutes with benzene (1:20). After 24 hours the precipitate was filtered. We obtained 0.46 g of pregnane-3α,20β-diol-11-one, m. p. 233-234° (from ethyl acetate).

The benzene mother liquor was evaporated in vacuo to dryness, followed by recrystallization of the residue from butyl acetate. We obtained 1.62 g of pregnan-3α-ol-11,20-dione, m. p. 173-173.5°, $[\alpha]^{20}$D +113° (1% solution in chloroform). Chromatographing of the butyl acetate mother liquor on dispersed aluminum oxide enabled us to isolate 0.25 g of pregnane-3,11,20-trione (benzene), 0.08 g of pregnan-3α-ol-11,20-dione (benzene — ether 10:2) and 0.05 g of pregnane-3α,20β-diol-11-one (benzene — ether 10:2). The last two compounds were eluted by the solvent as a mixture, and were separated by boiling with benzene. As a result, the total yield of pregnan-3α-ol-11,20-dione under these conditions was 61.6%, and that of pregnane-3α,20β-diol-11-one was 18.5%.

Using 75% of the required amount of reducing agent in a similar experiment gave a 57.4% yield of pregnan-3α-ol-11,20-dione and a 9.2% yield of pregnane-3α,20β-diol-11-one. When 50% of the optimum amount of sodium borohydride was used, we were able to obtain a 52.4% yield of pregnan-3α-ol-11, 20-dione and a 2% yield of pregnane-3α,20β-diol-11-one.

SUMMARY

1. It was established that the reduction of pregnane-3,11,20-trione with sodium borohydride in pyridine is not selective, and instead leads to a mixture of pregnan-3α-ol-11,20-dione and pregnane-3α,20β-diol-11-one, the ratios of which in the reaction mixture depend on the experimental conditions.

2. A method was developed for the purification of pregnan-3α-ol-11,20-dione, and the constants of the pure product were given.

3. A convenient method for the preparation of pregnan-3α-ol-11,20-dione was described.

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MECHANISM OF THE TRANSFORMATIONS OF TERTIARY ALCOHOLS OF THE CYCLOPROPANE SERIES UNDER THE INFLUENCE OF MINERAL AND ORGANIC ACIDS

VII. METHYL-CYCLOPROPYL-PHENYLETHYNYLCARBINOL AND METHYL-CYCLOPROPYL-ACETYLCARBINOL AND THEIR STABILITY IN ACID MEDIUM

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In previous papers we had shown that tertiary alcohols of the cyclopropane series in acid medium form unsaturated alcohols [1], ethers [2] and halides [3] as the result of a peculiar allylic rearrangement. Only when the reaction was run in the presence of pyridine were we able to react dimethylcyclopropylcarbinol with phosphorus trichloride to yield the cyclic chloride [4] corresponding to this alcohol. Other investigated homologs of dimethylcyclopropylcarbinol, namely methylisopropyl-, methyl-n-butyl- [4] and methyl-cyclopropyl-ethynyl-carbinols [5], even in the presence of pyridine, gave the unsaturated chlorides with an open chain of the carbon atoms when reacted with phosphorus trichloride. In the case of methyl-cyclopropyl-ethynylcarbinol, we made a detailed study of its transformations under the influence of hydrochloric, formic [6], and sulfuric [5] acids.

It seemed of interest, on the one hand, to observe the manner in which a cyclic alcohol with a substituted acetylenic hydrogen, like methyl-cyclopropyl-phenylethynylcarbinol, would react with either sulfuric or hydrochloric acid, and on the other hand, it was interesting to study the reaction for the hydration of methyl-cyclo-propyl-ethynylcarbinol and the properties of the methyl-cyclopropyl-acetylcarbinol formed here.

Methyl-cyclopropyl-phenylethynylcarbinol (I) was obtained from phenylacetylene and acetyltrimethylene, both in the presence of KOH by the A. E. Favorskii method [7] and through the Grignard compound. The structure of the alcohol was proved by its oxidation with potassium permanganate solution, where we isolated acetyltri-methylene, benzoic acid, and benzoylformic acid. When heated with alcoholic KOH solution, the compound decomposed into phenylacetylene and acetyltrimethylene. The infrared spectrum of this alcohol, taken in the 2900-3500 cm^{-1} region (LiF prism), showed a band at 3096 cm^{-1}, characteristic for the trimethylene ring.

When reacted with sulfuric acid (1:10) in the cold, or when heated for 1.5 hours, the methyl-cyclopropyl-phenylethynylcarbinol was recovered unchanged. Tarring occurred when the compound was heated with stronger sulfuric acid (1:5). This substantial stability of methyl-cyclopropyl-phenylethynylcarbinol in acid medium made it possible to assume that this alcohol would also prove to be stable when reacted with hydrochloric acid, and would convert to the cyclic chloride under these conditions. To check this assumption, we stirred methyl-cyclopropyl-phenylethynylcarbinol with hydrochloric acid (d 1.19), diluted with an equal volume of water, for 2 hours in the cold.

To prove its structure, the obtained chloride was oxidized with potassium permanganate solution, and it was also ozonized. Acetyltrimethylene and benzoic acid were isolated from the oxidation. We failed to obtain any neutral products from the ozonolysis, but did isolate benzoic acid and α-chloro-α-cyclopropylpropionic acid (III). The obtained results unequivocally establish the cyclic nature of the obtained chloride, being methyl-cyclopropyl-phenylethynylchloromethane (II).

CH₃ C≡C—C₆H₅ ... (structures at top)

$$\underset{(I)}{\begin{array}{c} CH_3 \quad C{\equiv}C{-}C_6H_5 \\ | \\ COH \\ | \\ CH \\ \diagdown \\ CH_2{-}CH_2 \end{array}} \xrightarrow{HCl} \underset{(II)}{\begin{array}{c} CH_3 \quad C{\equiv}C{-}C_6H_5 \\ | \\ CCl \\ | \\ CH \\ \diagdown \\ CH_2{-}CH_2 \end{array}} \xrightarrow{O_3} \underset{(III)}{\begin{array}{c} CH_3 \quad COOH \\ | \\ CCl \\ | \\ CH \\ \diagdown \\ CH_2{-}CH_2 \end{array}} + C_6H_5COOH$$
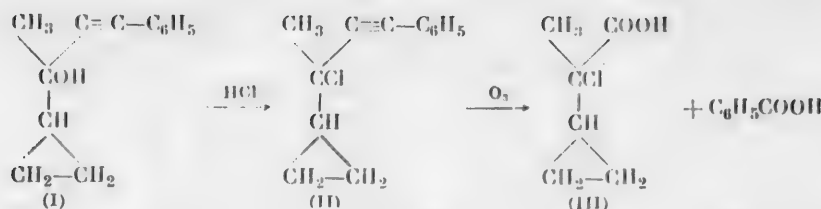
It is interesting to mention that the reaction of dimethylcyclopropylcarbinol with phosphorus trichloride in the presence of pyridine gives, besides the cyclic chloride, also its isomerization product — the unsaturated chloride, whereas the reaction of methylcyclopropyl-phenylethynylcarbinol with hydrochloric acid gave only chloride (II), and its isomerization to the chloride with an open chain of carbon atoms did not occur here.

Under the influence of sulfuric acid, methyl-cyclopropylethynylcarbinol (IV) is isomerized to the enyne alcohol (VII), 3-methyl-3-hexen-1-yn-6-ol [5]. We decided to check whether this isomerization would take place if the indicated alcohol was reacted with sulfuric acid in the presence of mercuric oxide, i.e., under conditions of its hydration. The reaction was run with 17% sulfuric acid, since 25% acid caused almost complete tarring of the product, while the reaction failed to go with either 6 or 12% acid. Depending on the manner in which the reaction mixture was worked up, different products were obtained. When the reaction products were extracted with ether directly from the reaction mixture, without previous steam distillation, we obtained the cyclic, unisomerized keto alcohol, methyl-cyclopropyl-acetylcarbinol (V), whereas if the reaction products were first steam distilled, and then extracted with ether, we obtained the isomeric keto alcohol, 3-methyl-3-hexen-2-on-6-ol (VI).

$$\underset{(IV)}{\begin{array}{c} CH_2 \quad C{\equiv}CH \\ | \\ COH \\ | \\ CH \\ \diagdown \\ CH_2{-}CH_2 \end{array}} \xrightarrow[HgO]{H_2SO_4} \underset{(V)}{\begin{array}{c} CH_3 \quad CO{-}CH_3 \\ | \\ COH \\ | \\ CH \\ \diagdown \\ CH_2{-}CH_2 \end{array}} \longrightarrow \underset{(VI)}{\begin{array}{c} CH_3{-}CO \\ \diagdown \\ \quad C{=}CH{-}CH_2{-}CH_2OH \\ \diagup \\ CH_3 \end{array}} .$$
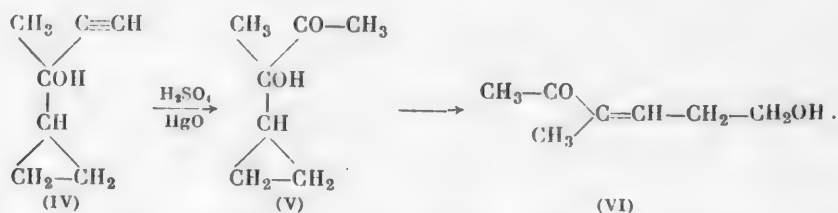
The oxidation of methyl-cyclopropyl-acetylcarbinol with potassium permanganate led to the isolation of acetyltrimethylene and acetic acid. To confirm the cyclic nature of the obtained alcohol, we took its infrared spectrum in the region from 2900 to 3200 cm⁻¹. Here two absorption maxima were found, characteristic for the trimethylene ring: 3006 and 3096 cm⁻¹.

The formation of a substantial amount of tar in the distillation of methyl-cyclopropyl-acetylcarbinol (V) caused us to postulate that when methyl-cyclopropyl-ethynylcarbinol is reacted with sulfuric acid and mercuric oxide, not only hydration occurs, but also the isomerization of alcohol (IV) to the enyne alcohol (VII), which, as is known [5], polymerizes with exceeding ease.

$$\underset{(VII)}{\begin{array}{c} CH_3 \\ \diagdown \\ \quad C{=}CH{-}CH_2{-}CH_2OH \\ \diagup \\ HC{\equiv}C \end{array}} \leftarrow (IV) \rightarrow \begin{array}{c} CH_3 \\ | \\ CO \\ | \\ CH \\ \diagdown \\ CH_2{-}CH_2 \end{array} + HC{\equiv}CH$$
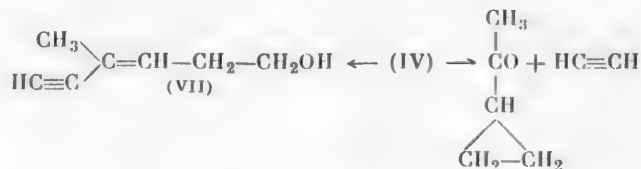
A substantial amount of tar is also formed in the steam distillation of the hydration products. When the steam-distilled reaction products were distilled, we isolated, besides alcohol (VI), also acetyltrimethylene, the formation of which can be explained by assuming a cleavage of the starting alcohol (IV) when heated in acid medium.

The structure of 3-methyl-3-hexen-2-on-6-ol (VI) was confirmed by taking its infrared spectrum in the 1600-2200 cm⁻¹ region. Very strong absorption was obtained at 1678 cm⁻¹ (either the double bond, or the ketonic

carbonyl group in conjugation with the double bond), and 1710 cm^{-1} (substituted ketones with an open chain). Weak absorption was observed at 2095 cm^{-1} (triple bond), which indicates that an acetylenic alcohol is present as impurity, in all probability, alcohol (VII). The amount of this impurity is exceedingly small, since it can be detected only spectroscopically, whereas the reaction with ammoniacal silver oxide solution is negative.

We prepared the 2,4-dinitrophenylhydrazones of both acetyltrimethylene and alcohol (VI). It should be mentioned that reaction of the cyclic keto alcohol with 2,4-dinitrophenylhydrazine solution led to its dehydration due to the sulfuric acid present in the solution, and the obtained 2,4-dinitrophenylhydrazone, as its complete analysis revealed, was not the derivative of the keto alcohol, but instead was the derivative of the corresponding unsaturated ketone. In the case of the unsaturated keto alcohol, the primary alcohol group present in it does not dehydrate, and the reaction with 2,4-dinitrophenylhydrazine proceeds normally.

An attempt was made to convert methyl-cyclopropyl-acetylcarbinol (V) to the corresponding chloro ketone, but this proved unsuccessful. Alcohol (V) was recovered unchanged, both when reacted with either dilute (1:1) or with concentrated hydrochloric acid, which again emphasizes the exceeding stability of this alcohol in acid medium.

This stability of methyl-acetyl-cyclopropylcarbinol can be explained by the presence of conjugation between the trimethylene ring and the carbonyl group, and in the case of methyl-cyclopropyl-phenylethynyl-carbinol, by the presence of the phenyl radical, found in conjugation with the triple bond. As is known, the presence of phenyl groups imparts stability to the trimethylene ring; thus, for example, Lipp [8] obtained a bromide when he reacted diphenylcyclopropylcarbinol with phosphorus tribromide, to which he assigned the formula of diphenylcyclopropylbromomethane, explaining its stability by the influence exerted by the phenyl groups.

EXPERIMENTAL

Methyl-cyclopropyl-phenylethynylcarbinol (I) was synthesized from acetyltrimethylene and phenylethynyl-magnesium bromide in 95-80% yield.

B. p. 168-169° (30 mm), n^{20}D 1.5570, d$^{20}_4$ 1.0257, MR$_D$ 57.46. C$_{13}$H$_{14}$OF$_3$F. Calc. 56.67.

Found %: C 83.65; H 7.76; OH 8.9. M 195. C$_{13}$H$_{14}$O. * Calculated %: C 83.87; H 7.57; OH 9.13. M 186.

We also synthesized methyl-cyclopropyl-phenylethynylcarbinol by the A. E. Favorskii method [7], which consisted in the addition of powdered KOH in small portions to an ether solution of phenylacetylene and acetyl-trimethylene. Yield 83.5%. B. p. 148-149° (16 mm).

Four grams of the alcohol was oxidized with potassium permanganate, first as a 1% solution, and then as a dry powder. After this, the manganese dioxide precipitate was filtered, and the neutral products were steam distilled. The obtained distillate was treated with a solution of 2,4-dinitrophenylhydrazine. After recrystallization from alcohol, the 2,4-dinitrophenylhydrazone (m. p. 143-145°) failed to depress the melting point when mixed with the 2,4-dinitrophenylhydrazone of authentic acetyltrimethylene. The solution of obtained salts was evaporated on the water bath, and then decomposed with dilute sulfuric acid; here the evolution of carbon dioxide was observed and a precipitate of benzoic acid was obtained, which was filtered and purified by sublimation, m. p. 118-121°; the mixed melting point with the authentic acid was not depressed. The filtrate was extracted with ether, and the extract was dried over Na$_2$SO$_4$. Evaporation of the ether left a small amount of a dark viscous oil, which slowly crystallized; after pressing on porous plate, the crystals gave a yellow 2,4-dinitrophenylhydrazone (m. p. 151°) with 2,4-dinitrophenylhydrazine, which did not depress the melting point when mixed with the 2,4-dinitrophenylhydrazone of authentic benzoylformic acid.

Found: equiv. 139. C$_8$H$_6$O$_3$. Calculated: equiv. 150.

Reaction of methyl-cyclopropyl-phenylethynylcarbinol with aqueous potassium hydroxide solution. A mixture of 3.5 g of the alcohol and 25 ml of 10% KOH solution was subjected to distillation from a Wurtz flask.

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* The Pregl method was used to make the elementary analyses. Low results were obtained when the analyses were made by the Korshun method.

The obtained distillate was separated into water layer and distilled phenylacetylene (characteristic odor, precipitate with ammoniacal silver oxide solution). The water layer was treated with 2,4-dinitrophenylhydrazine to give the 2,4-dinitrophenylhydrazone of acetyltrimethylene (m. p. 143°), which failed to depress the melting point when mixed with the 2,4-dinitrophenylhydrazone of authentic acetyltrimethylene.

Reaction of methyl-cyclopropyl-phenylethynylcarbinol with hydrochloric acid. A mixture of 14.5 g of the alcohol with 30 ml of hydrochloric acid (d 1.19) and 30 ml of water was stirred for 2 hours at room temperature. The upper layer was separated, and the lower layer was extracted with ether, after which both layers were washed with water, and dried over calcium chloride. After distilling off the ether, the residue was vacuum distilled.

The first fraction corresponded to methyl-cyclopropyl-phenylethynylchloromethane. Yield 9.1 g (41.5%).

B. p. 150-155° (14 mm), $n^{20}D$ 1.5762, d^{20}_4 1.1228, MR_D 60.34. $C_{13}H_{13}Cl_{F_3F_\triangle}$. Calculated: 60.01.

Found %: Cl 17.08. M 192. $C_{13}H_{13}Cl$. Calculated %: Cl 17.32. M 204.

The second fraction, b. p. 154-156° (14 mm), $n^{10}D$ 1.5580, 8 g, was the starting alcohol.

Oxidation of the obtained chloride. For 2.76 g of the chloride we took 10 g of $KMnO_4$, calculated on the basis that the compound was the enynic chloride with an open chain of carbon atoms, $C_6H_5C \equiv C - C(CH_3) =$ $=CHCH_2CH_2CH_2Cl$, but it proved that the oxidation of the chloride consumed a total of only 5.6 g. Oxidation of the cyclic chloride should require 5.7 g of $KMnO_4$. The manganese dioxide was filtered, the neutral products were steam distilled, and the distillate was treated with 2,4-dinitrophenylhydrazine solution. The obtained precipitate did not depress the mixed melting point with the 2,4-dinitrophenylhydrazone of acetyltrimethylene. Acidification of the solution of salts resulted in the evolution of carbon dioxide and the precipitation of benzoic acid with m. p. 120-121° (after sublimation), not depressing the mixed melting point with the authentic acid.

Ozonolysis of the chloride. We took 1.5 g of the chloride for ozonolysis. The ozonide was decomposed with water, and the solution was neutralized with sodium carbonate. Neutral products could not be found in the distillate. The solution of organic acid salts was evaporated, and then decomposed with sulfuric acid (1 : 5). The isolated benzoic acid had m. p. 121° (after sublimation). The mixed melting point was not depressed. The filtrate was extracted with ether, and the extract was dried over $MgSO_4$. Evaporation of the ether left a crystalline residue, which was pressed on porous plate, and then recrystallized from petroleum ether to give a substance with m. p. 114-116°.

Found %: Cl 22.41. Equiv. 146.8. $C_6H_9O_2Cl$. Calculated %: Cl 23.90. Equiv. 148.6.

The data correspond to methylcyclopropylchloroacetic acid.

Methyl-cyclopropyl-ethynylcarbinol (IV) was obtained by condensing acetyltrimethylene with acetylene in the presence of powdered KOH by the A. E. Favorskii method, worked out for the present case by A. P. Golovchanskaya [9]. Yield 90%. B. p. 53-55° (14 mm). Literature: b. p. 56-59° (15 mm) [9].

The hydration of methyl-cyclopropyl-ethynylcarbinol was run several times by various techniques in order to establish the optimum conditions.

1) Hydration by the Kucherov method. With vigorous stirring, 37 g of methyl-cyclopropyl-ethynylcarbinol was added dropwise in 1 hour to a solution of 3.7 g of mercuric oxide in 210 ml of 17% sulfuric acid, after which the stirring was continued for another 1.5 hours. The upper layer was separated, the aqueous layer extracted with ether, the extracts combined with the upper layer, and the whole dried over K_2CO_3. After distilling off the ether, the residue was vacuum distilled; a substantial amount of tar remained in the distillation flask. Yield 12.7 g (29.5%).

B. p. 73-75° (50 mm), $n^{20}D$ 1.4450, d^{20}_4 0.9832, MR_D 34.65. $C_7H_{12}O_{F_\triangle}$. Calculated 34.57.

Found %: C 65.97; H 9.41; OH number 1.09. M 120. $C_7H_{12}O$. Calculated %: C 65.62; H 9.38; OH number 1. M 128.

The obtained methyl-acetyl-cyclopropylcarbinol (V) is a colorless liquid with a pleasant odor; it turns yellow on standing. It decolorizes potassium permanganate solution. With 2,4-dinitrophenylhydrazine it gives a red precipitate with m. p. 119° (from alcohol).

Found %: C 53.67; H 5.20; N 19.12. $C_{19}H_{14}O_4N_4$. Calculated %: C 53.31; H 4.83; N 19.31.

Two grams of methyl-cyclopropyl-acetylcarbinol was oxidized with 0.9 g of potassium permanganate. The solution of neutral products gave a 2,4-dinitrophenylhydrazone with m. p. 146-147° (from alcohol). The mixed melting point with the 2,4-dinitrophenylhydrazone of authentic acetyltrimethylene was not depressed. The acid products were heated with silver carbonate. Analysis of the obtained silver salt corresponds to acetic acid.

Found %: Ag 64.81. $C_2H_3O_2Ag$. Calculated %: Ag 64.67.

To confirm the cyclic nature of the obtained keto alcohol (V), we took its infrared spectrum in the region from 2900 to 3200 cm^{-1}, using an IKS-11 apparatus and a LiF prism. The obtained absorption maxima at 3006 and 3086 cm^{-1} correspond to the vibrations of a three-membered ring.

2) The hydration of methyl-cyclopropyl-ethynylcarbinol was run under the above described conditions, after which the reaction products were steam distilled, and here considerable tarring was observed. After extraction with ether, drying, and removal of the solvent by distillation, the compound was distilled through a column. The following fractions were obtained at atmospheric pressure; 1st, 114-116°, 0.5 g (2.1%); 2nd, 116-156°, intermediate cut; and 3rd, 156-163°, 3.8 g (8.3%).

The constants of the first fraction corresponded to those of acetyltrimethylene; the obtained 2,4-dinitrophenylhydrazone did not depress the mixed melting point with the 2,4-dinitrophenylhydrazone of authentic acetyltrimethylene. The third fraction proved to be 3-methyl-3-hexen-2-on-6-ol (VI).

B. p. 156-163°, 71-72° (50 mm), $n^{20}D$ 1.4710, d^{20}_4 0.9414, MR_D 37.93. $C_7H_{12}O_2F$. Calculated 35.59.

Found: OH number 0.77; M 127. $C_7H_{12}O_2$. Calculated: OH number 1; M 128.

The obtained 3-methyl-3-hexen-2-on-6-ol 2,4-dinitrophenylhydrazone had m. p. 167-168° (from alcohol).

Found %: C 50.67; H 5.20; N 18.20. $C_{13}H_{16}O_5N_4$. Calculated %: C 50.65; H 5.19; N 18.18.

3) Hydration of methyl-cyclopropyl-ethynylcarbinol by the Locquin method [10]. A mixture of 110 g of the carbinol and 440 g of Deniges reagent, containing 200 g of sulfuric acid (d 1.84) and 30 g of mercuric oxide in 1 liter of water, was stirred in a flask, cooled with a stream of water. The immediately formed white precipitate soon changed to an oily layer, which was quickly separated, and placed in a flask cooled in ice water. The acid solution remaining in the reaction flask was heated to the boil, and the separated oily layer was added to it in drops. The obtained product was steam distilled, extracted with ether, dried over potassium carbonate, and distilled through a column. We obtained 4.2 g (3.3%) of 3-methyl-3-hexen-2-on-6-ol with b. p. 162-165°.

SUMMARY

1. The reaction of methyl-cyclopropyl-phenylethynylcarbinol with sulfuric and hydrochloric acids was studied.

2. It was established that methyl-cyclopropyl-phenylethynylcarbinol is recovered unchanged when reacted with sulfuric acid (1:10).

3. Reaction of methyl-cyclopropyl-phenylethynylcarbinol with dilute hydrochloric acid (1:1) yields the cyclic chloride, methyl-cyclopropyl-phenylethynylchloromethane.

4. The hydration of methyl-cyclopropyl-ethynylcarbinol was studied, and it was shown that the methyl-cyclopropyl-acetylcarbinol formed here is stable in acid medium at room temperature.

5. It was shown that the steam distillation of the reaction products from the hydration of methyl-cyclopropyl-ethynylcarbinol results in the isomerization of methyl-cyclopropyl-acetylcarbinol to the unsaturated keto alcohol — 3-methyl-3-hexen-2-on-6-ol — and its cleavage with the formation of acetyltrimethylene.

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SYNTHESIS AND POLYMERIZATION OF METHOXY-SUBSTITUTED (IN THE NUCLEUS) STYRENES

III. SYNTHESIS AND POLYMERIZATION OF TRIMETHOXYSTYRENES

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In a systematic study of the effect of introducing methoxy groups into the benzene ring of styrene on the polymerizability of the latter and the properties of the polymers obtained [1], it was of interest to study trimethoxystyrenes. As trimethoxystyrenes are not described in the literature, we undertook to synthesize 2,3,4- and 2,4,6-trimethoxystyrenes, using pyrogallol and phloroglucinol as starting materials. These trimethoxystyrenes were synthesized according to the general scheme which is shown for the instance of pyrogallol.
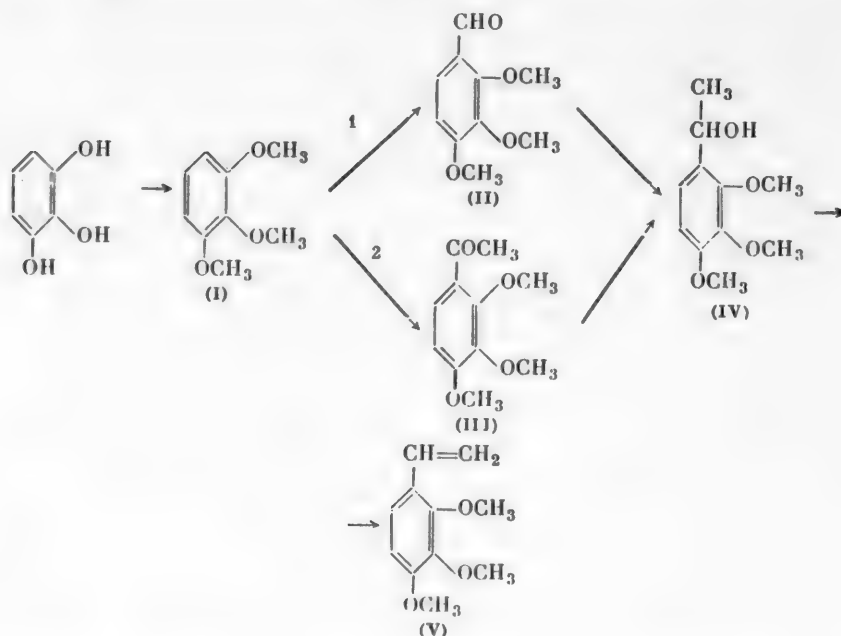
By the first route (2,3,4- and 2,4,6-trimethoxy)phenylmethylcarbinols (IV) and (VI) and 2,3,4-trimethoxystyrene (V), not previously described, were obtained and characterized. On attempting to dehydrate (2,4,6-trimethoxy)phenylmethylcarbinol (VI), splitting-out of acetaldehyde with formation of 1,3,5-trimethoxybenzene (VII) was observed.

$$\text{(VI)} \quad \longrightarrow \quad CH_3CHO + \text{(VII)}$$

Structures: CHOH—CH$_3$ substituted trimethoxybenzene (VI); H$_3$CO—OCH$_3$, OCH$_3$ (VII)
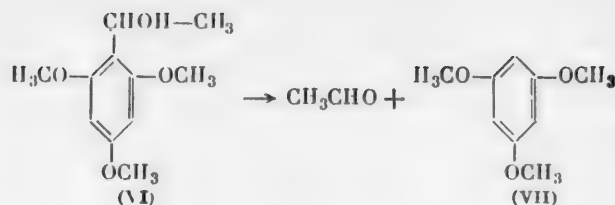
By the second route, Meerwein-Ponndorf reduction of trimethoxyacetophenone (III) [2] gave both carbinol (IV) and its ether, which did not permit the preparation of trimethoxystyrene (V) in pure form.

2,3,4-Trimethoxystyrene readily polymerizes on keeping and on heating (in the presence or in the absence of initiators), to form transparent, colorless, thermoplastic masses, soluble in benzene and carbon tetrachloride and insoluble in alcohols. The softening point of the polymer, found by the Wieck method, is 107°, and the characteristic viscosity is 3.1.
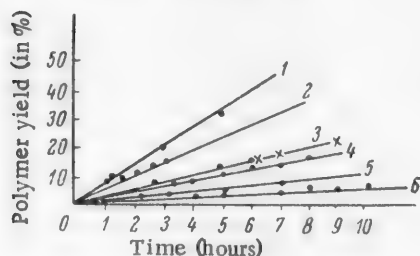
Polymerization of methoxy-substituted styrenes at 100°. 1) o-Methoxystyrene; 2) 2,3,4-trimethoxystyrene; 3) p-methoxystyrene; 4) 2,5-dimethoxystyrene; 5) m-methoxystyrene; 6) 3,4-dimethoxystyrene. The straight line for unsubstituted styrene coincides with line 3.

In order to study the effect of accumulation of methoxy groups in the benzene ring of styrene on the polymerizability of the latter under comparable conditions, the process of polymerization of 2,3,4-trimethoxystyrene in the absence of initiator was studied by the dilatometric method in a special apparatus [1].

Results of study of the polymerization of 2,3,4-trimethoxystyrene are given in the diagram. Data on the polymerization of mono- and dimethoxystyrenes, as well as unsubstituted styrene, are given for comparison. These data show that 2,3,4-trimethoxystyrene polymerizes at a much higher rate than 2,5- and 3,4-dimethoxystyrenes, p- and m-methoxystyrenes, and unsubstituted styrene. Furthermore, 2,3,4-trimethoxystyrene polymerizes more slowly than o-methoxystyrene. From this comparison it follows that the greater ease of polymerization of 2,3,4-trimethoxystyrene is due to the presence of one methoxy group in the ortho-position relative to the vinyl group in the substituted styrene molecule. At the same time the presence of the other two methoxy groups in the meta- and para-positions diminishes the total rate of polymerization of trimethoxystyrene (in comparison with o-methoxystyrene).

EXPERIMENTAL

1. Preparation of 1,2,3-trimethoxybenzene (I). Pyrogallol was methylated according to directions in [3]. Forty-two g of pyrogallol in 80 ml of acetone was methylated with 126 ml of dimethyl sulfate. The required alkalinity of the solution was maintained in this case by dropwise addition of 248 ml of 20% aqueous sodium hydroxide solution. The reaction was carried out for 2.5 hours at a water-bath temperature of 40-50°. The product was extracted with ether, the ethereal solution washed with alkali and water and dried, the ether driven off, and the residue distilled in vacuo or steam distilled. The product obtained by steam distillation was purer, but the yield in this case fell 15%. Yield 70-90%. B. p. 120° (7 mm); m. p. 43-44°. According to literature data: b. p. 241°, m. p. 45° [8].

2. Preparation of 2,3,4-trimethoxybenzaldehyde (II) [6]. To a mixture of 43.4 g of phosphorus oxychloride and 37.2 g of N-methylformanilide was added 33.6 g of trimethoxybenzene, with stirring, during 1.5 hours. The mixture was heated for 2.3 hours at 40-50° and poured into 500 ml of water. The product was extracted with ether and the ethereal solution dried and distilled. Aldehyde (II) was obtained in 80-90% yield. The latter was an oil which solidified to form crystals with m. p. 30°, b. p. 151-153° (5 mm). According to literature data [5]: m. p. 30°, b. p. 151-153° (5 mm), 168-170° (12 mm).

Found %: C 61.24; H 6.35. $C_{10}H_{12}O_4$. Calculated %: C 61.22; H 6.12.

For identification of (II) the phenylhydrazone was prepared; crystals with m. p. 151.5-152.5°.

Found %: N 10.17. $C_{16}H_{18}O_3N_2$. Calculated %: N 9.79.

3. Preparation of (2,3,4-trimethoxyphenyl)methylcarbinol (IV). To the ethereal methylmagnesium bromide solution obtained from 9.6 g of magnesium and 38 g of methyl bromide was added an ethereal solution of 58.8 g of aldehyde (II). The mixture was stirred for 2 hours more and decomposed by pouring into a mixture of ice and ammonium chloride. The product was extracted with ether, the solution dried, and the ether driven off. The residue was distilled in vacuo, (IV) being obtained in the form of a slowly crystallizing oil. Its properties and analytical data are given in the table. An alcoholic solution of (IV) does not give a precipitate with phenylhydrazine solution.

Properties of Synthesized Compounds

Substance	B. p. (pressure in mm)	Melting point	% C		% H		% OCH₃	
			found	calc.	found	calc.	found	calc.
(2,3,4-Trimethoxy-phenyl)methylcarbinol (IV) $C_{11}H_{16}O_4$	150° (5)	35—37°	62.25	62.26	7.53	7.46	43.97	43.86
2,3,4 Trimethoxy-styrene (V) $C_{11}H_{14}O_3$	105 (1) 108 (2)	—	68.20	68.04	7.13	7.20	47.90	47.9
(2,4,6-Trimethoxy-phenyl)methylcarbinol (VI) $C_{11}H_{16}O_4$	—	75.5—76.5	62.50	62.26	7.60	7.46	43.85	43.86

4. Preparation of 2,3,4-trimethoxystyrene (V) A toluene solution of alcohol (IV), containing a small amount of hydroquinone, was introduced dropwise into a distilling flask containing potassium bisulfate at an oil-bath temperature of 150-160° and 20-30 mm pressure. In this case, a mixture of water, substance (V), and toluene collected in the receiver. This mixture was extracted with ether and the ethereal solution washed with alkali, water, and saturated calcium chloride solution. After drying and removal of ether the residue was distilled in vacuo, 2,3,4-trimethoxystyrene being obtained in the form of a colorless liquid with a styrene-like odor and a monomer content of 97.7%.

d^{20}_{20} 1.0964, $n^{20}D$ 1.5465, MR_D 56.13; calc. 56.05.

The boiling point and analyses of (V) are given in the table.

5. Preparation of 2,3,4-trimethoxyacetophenone (III) [4]. To a solution prepared by cautious heating of 16.8 g of trimethoxybenzene (I) and 6 g of acetic anhydride was added 150 g of polyphosphoric acid [5], and the mixture was stirred in a water bath at 45° until solution was complete. The product was poured into 600 ml of ice water and extracted with ether. The solution was dried, the ether driven off, and the residue distilled in vacuo, (III) being obtained in 85% yield. B. p. 160-163° (10 mm); according to [4]; b. p. 179-180° (18 mm).

6. Reduction of 2,3,4-trimethoxyacetophenone and attempts at dehydration of the product obtained. To the alkoxide prepared from 7.5 g of aluminum and 70 ml of isopropyl alcohol was added a solution of 52 g of trimethoxyacetophenone (III) in 250 ml of anhydrous isopropyl alcohol. The mixture was heated in a steam bath for 5-6 hours; in this case, the acetone formed and the excess isopropyl alcohol were distilled off. The residue was decomposed by pouring it into a mixture of ice and hydrochloric acid, the product extracted with ether, the solution dried over anhydrous magnesium sulfate, and the ether distilled off. The residue was a heavy, yellow oil, which slowly crystallized. After 3-fold recrystallization from petroleum ether, crystals with m. p. 104-105° were obtained. On heating of the reduction product of (III) with potassium bisulfate there was formed substance (V) — a liquid with a styrene-like odor and a double-bond content of 91.5%, which could not be increased by further purification of the substance obtained. It polymerized on standing and on heating.

7. Preparation of 1,3,5-trimethoxybenzene (VII). Phloroglucinol was methylated in the same way as pyrogallol [3], but the yield of product amounted only to 40-60%. It should be noted that commercial, "pure" phloroglucinol contains 22.4% water; before use, therefore, it was necessary to heat the phloroglucinol at 120°. 1,3,5-Trimethoxybenzene consisted of crystals with m. p. 50-51°, b. p. 115-120° (2 mm); according to [3]; m. p. 50°.

8. Preparation of 2,4,6-trimethoxyacetophenone [7]. To a mixture of 10 g of (VII) and 10 ml of acetyl chloride, 5 ml of concentrated sulfuric acid was added dropwise, with stirring. After 12 hours, 200 ml of water was added to this mixture, and the solid residue of 2,4,6-trimethoxyacetophenone was filtered out and recrystallized from aqueous acetone. Yield 90%. Shiny, white leaflets with m. p. 101-101.5°; according to [7]; m. p. 97-102°.

9. Reduction of 2,4,6-trimethoxyacetophenone. Reduction by aluminum isopropoxide was carried out exactly as in the case of the 2,3,4-isomer, but (2,4,6-trimethoxyphenyl)methylcarbinol could not be isolated. On decomposition of the aluminum complex a thick, gummy tar was obtained which was soluble in benzene and ether and insoluble in alcohols.

10. Preparation of 2,4,6-trimethoxybenzaldehyde [8]. A rapid current of dry hydrogen chloride was passed into a mixture of 33.6 g of 2,3,5-trimethoxybenzene (VII) and 35.1 g of anhydrous zinc cyanide in 200 ml of absolute ether until the mixture was saturated (6-9 hours). Then the ether was poured off (the aldehyde is insoluble in ether) and the residue decomposed with 2 liters of water at 80°. Heating at a higher temperature caused resinification of the aldehyde and sharply decreased the yield. The aqueous solution was neutralized with soda until the precipitation of basic zinc salts ceased, and the precipitate of the latter was filtered off. Part of the aldehyde was retained by this precipitate and was extracted from it by boiling methyl alcohol. The bulk of the aldehyde separated from the aqueous solution on standing. Total yield 60-65%. 2,4,6-Trimethoxybenzaldehyde consisted of barely yellowish crystals with m. p. 118-119°, which corresponds to [9]. The phenylhydrazone consisted of crystals with m. p. 116-117°.

Found %: N 10.01. $C_{16}H_{18}O_3N_2$. Calculated %: N 9.79.

In the preparation of 2,4,6-trimethoxybenzaldehyde by the formylation reaction [6], which was analogous to the preparation of 2,3,4-trimethoxybenzaldehyde, the yield of crude product amounted to 95%; the yield after recrystallization was 81%.

11. Preparation of (2,4,6-trimethoxyphenyl)methylcarbinol (VI). To an ice-cooled solution of 0.2 mole of methylmagnesium bromide was added an ether or benzene solution of (IX), with stirring, and the reaction mass was heated for 1.5-2 hours and then decomposed by pouring it into a mixture of ice and ammonium chloride. The carbinol was filtered out and recrystallized from a benzene-hexane mixture (1:3). Yield of crude product, 80%. The properties of (VI) and analytical data are given in the table.

12. Dehydration of (2,4,6-trimethoxyphenyl)methylcarbinol (VI). The dehydration of (VI) was carried out in the usual way with 20% of potassium bisulfate at 160° and 20-30 mm pressure, which was then lowered. At 110-120° (2-3 mm) a substance was distilled off, which crystallized in the condenser. M. p. 51-52° after recrystallization from hexane. Unsaturation 22.8-23.5% (determined by various methods).

On dehydration of carbinol (VI), acetaldehyde was collected in the receiver, which was cooled with solid carbon dioxide; the aldehyde was identified in the usual way. The crystalline product obtained in the dehydration process corresponds, according to melting point, data of elementary analysis, and determination of the percentage of methoxy groups present, to 1,3,5-trimethoxybenzene (VII).

Found %: C 64.38; H 7.51; OCH₃ 55.0. $C_9H_{12}O_3$. Calculated %: C 64.34; H 7.14; OCH₃ 55.3.

Thus, when substance (VI) is heated with KHSO₄, instead of dehydration, splitting out of acetaldehyde occurs and 1,3,5-trimethoxybenzene is formed.

Attempts to prepare 2,4,6-trimethoxystyrene from substance (VI) through the secondary chloride with subsequent splitting-out of the elements of hydrogen chloride by boiling in pyridine, as well as by cleavage of the sulfite derivative (VIII) obtained from carbinol (VI) and thionyl chloride, also failed.

In both cases a brittle, colored polymer was obtained.

(VIII)
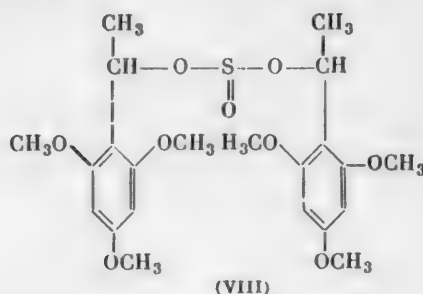
13. Polymerization of 2,3,4-trimethoxystyrene (V). The polymerization was studied in a mercury dilatometer [1] at 100° in the absence of initiator. The monomer was distilled into the dilatometer bulb in vacuo, and the capillary over the bulb was resealed. Polymer yield was determined by bromination of the residual monomer in carbon tetrachloride. Results of the experiments in polymerization are given in the diagram.

SUMMARY

1. (2,3,4-Trimethoxyphenyl)methylcarbinol, (2,4,6-trimethoxyphenyl)methylcarbinol, and 2,3,4-trimethoxystyrene, which have not been described previously, were prepared and characterized.

2. It has been shown that, when (2,4,6-trimethoxyphenyl)methylcarbinol is heated with potassium bisulfate, acetaldehyde is split out and 1,3,5-trimethoxybenzene is obtained.

3. The process of polymerization of 2,3,4-trimethoxystyrene at 100° has been studied. It has been shown that the ease of polymerization of 2,3,4-trimethoxystyrene is due to the presence of one methoxy group in the ortho-position relative to the vinyl group of the substituted styrene.

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SYNTHESIS OF γ-AMINO ACIDS AND PYRROLIDONES*

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The study of the reaction of unsaturated nitro compounds with substances containing mobile hydrogen atoms in methylene and methyl groups suggested to us the idea of using the condensation of nitroolefins with ethyl malonate [1-3] to develop a method of synthesis of amino acids of the γ-series.

The latest investigations show that these compounds are biochemically important and interesting substances [4-7]. For instance, γ-aminobutyric acid takes part in processes of biochemical reamination as a partner of γ-ketoglutaric acid [4-6]. The great practical importance of compounds of the pyrrolidone series is also generally known; they promote the attainment of functional and structural maturity by cells and are used as regulators of plant growth [8, 9].

Existing methods of preparation of γ-amino acids amount to oxidation of piperidine derivatives, reduction of keto-acid hydrazones and acid nitriles and dinitriles, and hydrolysis of pyrrolidones.

Methods of synthesizing pyrrolidones are closely related to methods of synthesizing α-amino acids. They are prepared by cyclization of γ-amino acids and their acid chlorides and also γ-halocarboxylic acid nitriles and amides, and by reduction of nitrocarboxylic acid esters and amides, β-cyanoesters, and succinimides. Most of the work of recent years on the synthesis of pyrrolidones deals with their preparation from lactones.

Consideration of methods of synthesis of γ-amino acids and pyrrolidones, described in the literature, shows that their use is often restricted by poor availability of the starting materials. The most detailed syntheses have been worked out for the very simple γ-aminobutyric acid. In those cases where it proves necessary to prepare more complex γ-amino acids existing methods become clearly inadequate.

In the present work, in order to develop a method of preparing γ-amino acids, the sodium derivative of methyl malonate was brought into reaction with aliphatic, aromatic, and heterocyclic nitroolefins (β-iso-propylnitroethylene [10], p-methoxy-ω-nitrostyrene [11], p-hydroxy-m-methoxy-ω-nitrostyrene [12], β-furylnitroethylene [13], β-thienylnitroethylene [14]). The condensation was carried out through the formation of nitrodicarbomethoxy derivatives (I), which on reduction over Raney nickel catalyst formed carbomethoxy-pyrrolidones (II); acid hydrolysis of the carbomethoxypyrrolidones led to substituted γ-aminobutyric acids (III), whereas alkaline hydrolysis led to pyrrolidonecarboxylic acids (IV). On heating, γ-amino acids (III) and pyrrolidonecarboxylic acids (IV) were converted to pyrrolidones (V); hydrolysis of the pyrrolidones again led to γ-amino acids. The acetyl derivative of 4-(4'-methoxyphenyl)pyrrolidone-2 (VI) also was synthesized.

$$O_2N-CH=CH \qquad + \qquad CH_2(COOCH_3)_2$$
$$\overset{|}{R}$$

$$O_2NCH_2CHCH(COOCH_3)_2$$
$$\overset{|}{R} \quad (I)$$

$$\Big\downarrow H_2$$

$$R-CH-CH-COOCH_3$$
$$\begin{array}{cc} | & | \\ CH_2 & C=O \\ \diagdown & \diagup \\ & NH \\ & (II) \end{array}$$

HCl (1:1) ↙ $\qquad$ ↘ KOH 10%

$$NH_2CH_2CHCH_2COOH$$
$$\overset{|}{R} \quad (III)$$

$$R-CH-CH-COOH$$
$$\begin{array}{cc} | & | \\ CH_2 & C=O \\ \diagdown & \diagup \\ & NH \quad (IV) \end{array}$$

(CH₃CO)₂O ↓ (left)

← Heating / KOH 10% →

Heating ↓ (right, IV)

$$R-CH-CH_2$$
$$\begin{array}{cc} | & | \\ CH_2 & C=O \\ \diagdown & \diagup \\ & N-COCH_3 \\ & (VI) \end{array}$$

← (CH₃CO)₂O

$$R-CH-CH_2$$
$$\begin{array}{cc} | & | \\ CH_2 & C=O \\ \diagdown & \diagup \\ & NH \\ & (V) \end{array}$$

(Ia)–(Va) $R = -CH(CH_3)_2$

(Ib)–(VIb) $R = \langle\!\!\langle\ \rangle\!\!\rangle-OCH_3$

(Ic)–(Vc) $R = \langle\!\!\langle\ \rangle\!\!\rangle-OH$
$\qquad\qquad OCH_3$

(Id)–(Vd) $R = \Big[\ \Big]$ (furyl, O)

(Ie)–(Ve) $R = \Big[\ \Big]$ (thienyl, S)
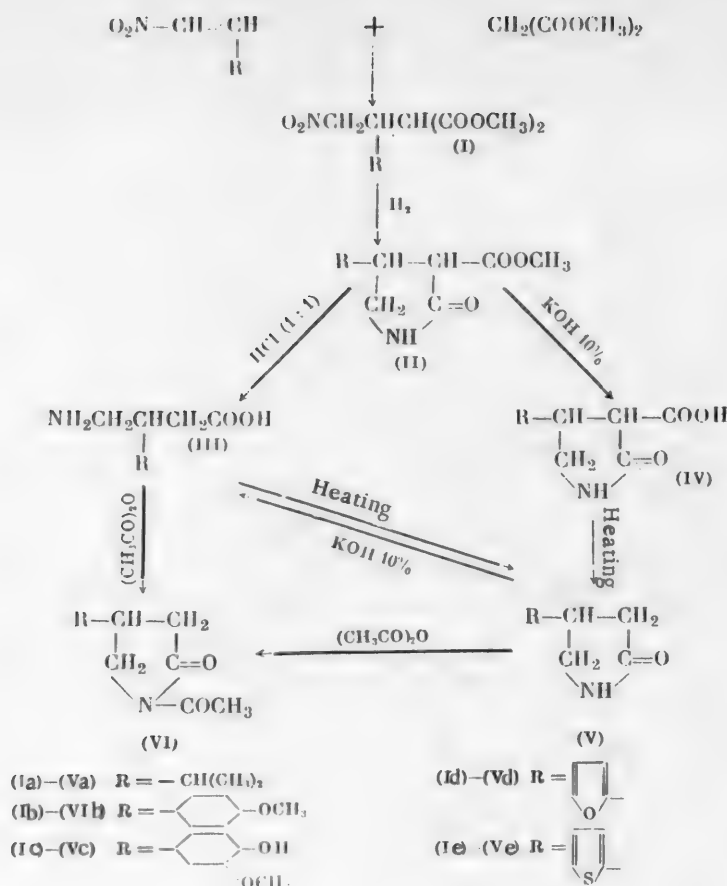
In the first step of the conversions a solution of the nitroölefin in anhydrous methanol was added to a solution of sodiomethyl malonate* also in anhydrous methanol; mixing the solutions in the opposite order often caused polymerization of the nitroölefin. The condensations were carried out at a reduced temperature; increase of temperature above 20° led to considerable resin formation. On completion of the reaction the mixture was acidified with acetic acid.

The reduction was carried out in methanol at room temperature, the catalyst (Raney nickel) being saturated beforehand with hydrogen; from the quantity of hydrogen absorbed it could be deduced that only the nitro group was reduced, whereas the carboxyl groups remained unchanged.

Pyrrolidonecarboxylic acids (IV) were isolated from the alkaline solutions obtained after hydrolysis of the carbomethoxypyrrolidones (II) by acidification with dilute hydrochloric acid; on heating to the melting point they were converted to the corresponding pyrrolidones. Hydrolysis of the latter by 10% potassium hydroxide solution, followed by neutralization with dilute hydrochloric acid, resulted in the formation of γ-amino acids. On treatment of 4-amino-3-(4'-methoxyphenyl)butyric acid with acetic anhydride, N-acetyl-4-(4'-methoxy-phenyl)pyrrolidone-2 was obtained. This same product was formed on acetylation of the corresponding pyrrolidone.

As a result of the conversions described, there were synthesized five γ-amino acids: 4-amino-3-iso-propylbutyric acid (IIIa), 4-amino-3-(4'-methoxyphenyl)butyric acid (IIIb), 4-amino-3-(3'-methoxy-4'-hydroxyphenyl)butyric acid (IIIc), 4-amino-3-(α-furyl)butyric acid (IIId), and 4-amino-3-(α-thienyl)butyric acid (IIIe), and the five corresponding pyrrolidones: 4-isopropylpyrrolidone-2 (Va), 4-(4'-methoxyphenyl)

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* The sodium derivative of methyl malonate was obtained as a result of transesterification of ethyl malonate on its reaction with sodium methoxide.

pyrrolidone-2 (V b), 4-(3'-methoxy-4'-hydroxyphenyl)pyrrolidone-2 (Vc), 4-(α-furyl)pyrrolidone-2 (Vd), and 4-(α-thienyl)pyrrolidone-2 (Ve).

A detailed description of the proposed method of synthesis of γ-amino acids is given for the case of the preparation of 4-amino-3-(4'-methoxyphenyl)butyric acid.

Melting points, yields, and data of elementary analysis of the products obtained are given in the table.

EXPERIMENTAL

Methyl 4-nitro-3-(4'-methoxyphenyl)-2-carbomethoxybutyrate (Ib). To a vigorously stirred solution of sodiomethyl malonate, prepared from 0.23 g of metallic sodium,* 1.6 g of ethyl malonate, and 10 ml of anhydrous methanol was added a suspension of 1.79 g of p-methoxy-ω-nitrostyrene in 50 ml of anhydrous methanol.** The temperature was kept at 20°.

After 30 minutes the reaction mixture was acidified with acetic acid and poured into 50 g of a water-ice mixture;*** crystallization began immediately. Yield 3 g (96.5%).

Methyl 4-nitro-3-(4'-methoxyphenyl)-2-carbomethoxybutyrate (Ib) consisted of colorless, prismatic crystals, m. p. 99.5° (from methanol).

3-Carbomethoxy-4-(4'-methoxyphenyl)pyrrolidone-2 (IIb). Two g of methyl 4-nitro-3-(4'-methoxyphenyl)-3-carbomethoxybutyrate (Ib) was dissolved in 100 ml of methanol and reduced at room temperature in the presence of Raney nickel catalyst saturated beforehand with hydrogen. During 2 hours 480 ml of hydrogen was absorbed (theoretically, 430 ml should have been absorbed). Then the catalyst was filtered off and the solution concentrated to 5 ml at reduced pressure. The crystals formed after 12 hours were filtered out. Yield 1.58 g (89%).

3-Carbomethoxy-4-(4'-methoxyphenyl)pyrrolidone-2 (IIb) — colorless, prismatic crystals with m. p. 108.5° (from methanol).

4-Amino-3-(4'-methoxyphenyl)butyric acid (IIIb). A 3.37 g quantity of 4-(4'-methoxyphenyl)pyrrolidone-2 (IIb) was boiled for 10 hours with 20 ml of hydrochloric acid (1:1), after which the solution was evaporated to dryness. The residue was dissolved in 5 ml of water and neutralized to litmus with 10% soda solution; within a few minutes shiny lamellae separated out. Yield 2.66 g (94%).

4-Amino-3-(4'-methoxyphenyl)butyric acid (IIIb), m. p. 193° (decomp.), shiny, colorless leaflets (from water).

3-Carboxy-4-(4'-methoxyphenyl)pyrrolidone-2 (IVb). A 1.67 g quantity of 3-carbomethoxy-4-(4'-methoxyphenyl)pyrrolidone-2 (IIb) was boiled for 3 hours with the theoretical quantity of 10% potassium hydroxide solution. Then the cooled solution was acidified with hydrochloric acid (1:1); on rubbing with a glass rod, fine, shiny crystals separated out. Yield 1.49 g (95%).

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* On condensation of p-hydroxy-m-methoxy-ω-nitrostyrene with ethyl malonate a twofold molar excess of metallic sodium was necessary.

** Contrary to the given directions, in the reaction with ethyl malonate, β-isopropylnitroethylene was dissolved in 15 ml of anhydrous methanol. After acidification the methanol was distilled off at reduced pressure, and the residue in the flask was dissolved in ether, washed with water, dried over anhydrous sodium sulfate, and, after driving off the ether, distilled in vacuo.

*** To isolate the 4-nitro-3-(α-thienyl)-2-carbomethoxybutyric acid (Ie) obtained after acidifying the reaction mixture and distilling off the methanol in vacuo, the residue was dissolved in a few milliliters of ether; the sodium acetate was filtered off and the solution cooled to 15°, the container being continuously rubbed with a glass rod; a finely crystalline precipitate of substance (Ie) separated out.

Melting Points, Yields, and Analyses of Compounds Obtained

Compound	Yield (in %)	Melting point	Found (%)				Calculated (%)			
			C	H	N	S	C	H	N	S
Ia	46	B. p. 127—128° (0.7mm)	48.87, 48.89	7.13, 7.21	5.89, 5.83	} —	48.58	6.93	5.67	—
IIa	92.9	99 methanol	58.9, 58.73	8.75, 8.75	7.82, 7.55	} —	58.36	8.16	7.56	—
IIIa	81.0	165 (water)	58.19, 57.89	10.25, 10.14	9.92, 9.89	} —	57.9	10.41	9.64	—
IVa	98.7	151 (water)	55.98, 55.87	7.72, 7.86	8.36, 8.37	} —	56.12	7.65	8.18	—
Va	99	100 (petroleum ether)	65.83, 65.91	10.34, 10.49	11.01, 11.08	} —	66.01	10.3	11.01	—
Ib	96.5	99.5 methanol	54.11, 54.21	5.75, 5.63	4.54, 4.46	} —	54.01	5.55	4.5	—
IIb	89	108.5 methanol	62.75, 62.68	6.28, 6.25	5.69, 5.76	} —	62.64	6.07	5.62	—
IIIb	94	193 (water)	63.15, 63.12	7.39, 7.53	6.86, 6.85	} —	63.19	7.23	6.69	—
IVb	95	152 (water)	61.35, 61.35	5.93, 6.01	6.22, 6.22	} —	61.14	5.57	5.95	—
Vb	76.6	130 methanol	69.19, 69.36	7.15, 7.11	7.17, 7.17	} —	69.08	6.85	7.32	—
VIb	64.5	76 (aqueous ethanol)	66.71, 66.69	6.59, 6.91	6.06, 6.06	} —	66.95	6.43	6.00	—
Ic	92.7	119—120 methanol	51.37, 51.55	5.55, 5.26	4.48, 4.38	} —	51.37	5.23	4.28	—
IIc	84	145 methanol	59.04, 58.83	5.86, 5.98	5.29, 5.37	} —	58.86	5.7	5.28	—
IIIc*	50.0	213 (water)	50.39, 50.56	6.35, 6.22	5.61, 5.58	} —	50.48	6.16	5.35	—
IVc	86.6	177 (water)	57.35, 57.65	5.64, 5.52	5.64, 5.50	} —	57.33	5.22	5.58	—
Vc	60	65 methanol	} —	— {	6.86, 6.81	} —			6.76	—
Id	87.5	54 methanol	48.40, 48.36	4.86, 5.21	5.3, 5.18	} —	48.65	4.83	5.16	—
IId	87	97.5 methanol	57.44, 57.51	5.56, 5.64	6.99, 6.93	} —	57.41	5.3	6.69	—
IIId	66	173 (aqueous ethanol)	55.63, 55.35	6.45, 6.27	8.41, 8.53	} —	56.78	6.55	8.28	—
IVd	72.0	131 (water)	55.63, 55.35	4.41, 4.5	7.29, 7.57	} —	55.38	4.65	7.1	—
Vd	70.9	83.5 (methanol)	63.61, 63.64	5.95, 5.91	9.54, 9.52	} —	63.56	6.00	9.27	—

* IIIc was analyzed in the form of the hydrochloride, since the free amino acid was difficult to purify.

Compound	Yield (in %)	Melting point	Found (%)				Calculated (%)			
			C	H	N	S	C	H	N	S
Ie	81.5	35.5° (ether)	46.21, 46.27	4.39, 4.33	4.74, 4.79	11.08, 11.17	45.99	4.6	4.88	11.15
IIe	62	115.5 (methanol)	53.09, 53.07	4.57, 4.65	6.30, 6.38	13.66, 13.76	53.33	4.92	6.22	14.2
IIIe	80	206 (aqueous ethanol)	52.04, 52.10	5.67, 5.86	7.41, 7.35	17.28, 17.34	51.89	5.45	7.02	17.28
Ve	44	87.5 (petroleum ether)	—	—	8.48, 8.54	—	—	—	8.38	—

3-Carboxy-4-(4'-methoxyphenyl)pyrrolidone-2 (IVb) — m. p. 152° (decomp.), colorless needles (from water).

4-(4'-Methoxyphenyl)pyrrolidone-2 (Vb). Three g of 3-carboxy-4-(4'-methoxyphenyl)pyrrolidone-2 (IVb) was heated at 160° until the evolution of gas bubbles ceased. The cooled product crystallized. Yield 1.87 g (76.6%).

4-(4'-Methoxyphenyl)pyrrolidone-2 (Vb) — colorless needles with m. p. 130° (from methanol).

N-Acetyl-4-(4'-methoxyphenyl)pyrrolidone-2 (VIb). A 0.57 g quantity of 4-amino-3-(4'-methoxyphenyl)butyric acid (IIIb) was boiled with 2 ml of acetic anhydride for 3.5 hours. The cooled reaction mixture was filtered and poured into water. The oil formed gradually crystallized. Yield 0.42 g (64.5%).

N-Acetyl-4-(4'-methoxyphenyl)pyrrolidone-2 (VIb) — m. p. 76°, fine, acicular crystals from aqueous alcohol.

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SYNTHESIS AND REACTIONS OF β-CYANOETHYLSILANES

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The first representative of this class of organosilicon compounds was prepared by dehydration of β-trimethylsilylpropionamide [1]. Further, β-trichloro- (or tribromo-)silylpropionitrile [2, 3] was prepared by a direct method of synthesis according to the scheme:

$$XCH_2CH_2CN + Si/Cu \xrightarrow{370-380°} X_3SiCH_2CH_2CN \qquad (1)$$
$$\text{where} \quad X = Cl \text{ or } Br.$$

Finally, β-cyanoethylsilanes were prepared by cyanoethylation of partly substituted silanes [2-8] according to the reaction:

$$RSiCl_2H + CH_2=CHCN \xrightarrow[70-180°]{\text{catalysts}} RSi(Cl_2)CH_2CH_2CN, \qquad (2)$$
$$\text{where} \quad X = Cl, \ CH_3, \ C_2H_5.$$
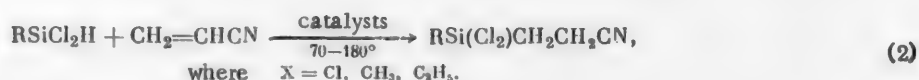
The indicated investigations showed that β-cyanoethylsilanes, in contrast to α-cyanoalkylsilanes [3, 9-11], can react through the cyano group and thus are of interest as starting materials for the synthesis of various organosilicon compounds containing functional carbon.

In the present investigation we describe a new method of synthesis of β-cyanoethylsilanes, namely, β-cyanoethyltrialkylsilanes. To prepare them we used the well-known reaction [12] of alkylation of nitriles by alkyl halides, which was carried out with the aid of sodium or sodium amide and usually proceeded in a stepwise manner according to the scheme:

$$RX + R'CH_2CN + Na \longrightarrow RR'CHCN + NaX + \tfrac{1}{2}H_2, \qquad (3)$$

$$RX + RR'CHCN + Na \longrightarrow R_2R'CCN + NaX + \tfrac{1}{2}H_2, \qquad (4)$$
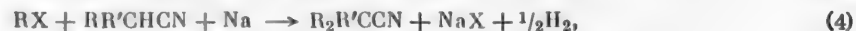
where R = alkyl or aryl; R' = alkyl, aryl, or hydrogen; X = Cl or Br.

We prepared β-cyanoethyltrialkylsilanes through the reaction:

$$R(CH_3)_2SiCH_2X + CH_3CN + Na \longrightarrow R(CH_3)_2SiCH_2CH_2CN + NaX + \tfrac{1}{2}H_2 \qquad (5)$$
$$\text{where } R = CH_3, \ C_2H_5; \ X = Cl \text{ or } I$$
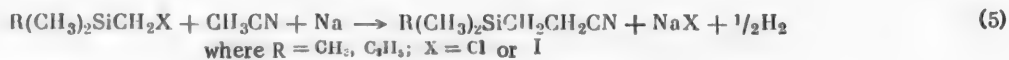
In the case of chloromethyltrialkylsilanes, NaI was used as catalyst.

We were unable to isolate the dialkylation products of acetonitrile [Reaction (4)], obviously owing to the high boiling points of these compounds, although a considerable nondistillable residue was left in the distilling flask, especially in the case of chloromethyltrialkylsilanes. The highest yield of a silicon-containing nitrile (52%) was obtained when iodomethyltrimethylsilane was used. It should be noted that α-iodoalkyltrialkylsilanes are now readily available [13].

β-Cyanoethyltrimethylsilane, obtained through Reaction (5), proved identical with the compound obtained earlier [1, 2, 6]. Furthermore, its structure was proved by the reactions:

$$(CH_3)_3SiCH_2CH_2CN + RMgX \longrightarrow (CH_3)_3SiCH_2CH_2COR, \tag{6}$$

$$(CH_3)_3SiCH_2CH_2COR + C_6H_5MgBr \longrightarrow (CH_3)_3SiCH_2CH_2CR(C_6H_5)OH, \tag{7}$$
$$\text{where } R = CH_3, C_6H_5.$$
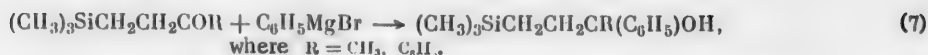
The ketone $(CH_3)_3SiCH_2CH_2COCH_3$, which we synthesized through Reaction (6), also was prepared earlier by other methods [2, 14].

It should be pointed out that the silicoalkylation reaction has already been attempted by Prober [10] in the case of the interaction of trimethylchlorosilane, sodium, and acetonitrile; however, the expected $(CH_3)_3SiCH_2CN$ was obtained in only 2% yield. Here the reaction proceeded according to a different scheme, as a result of which $(CH_3)_3SiNC$ and $(CH_3)_3Si-N=C=CHSi(CH_3)_3$ were formed (in 25 and 27% yields, respectively), together with some other products.

In the present investigation we also followed the ratio of β trichlorosilylpropionitrile, prepared according to Scheme (1), to various reagents and established that β-cyanoethylsilanes with functional groups attached to silicon can be prepared through Reactions (8), (9), and (10), given below.

$$Cl_3SiCH_2CH_2CN + 3ROH + 3C_5H_5N \longrightarrow (RO)_3SiCH_2CH_2CN + 3[HCl \cdot C_5H_5N], \tag{8}$$
$$\text{where } R = C_2H_5 \text{ or } CH_2CH=CH_2.$$

$$Cl_3SiCH_2CH_2CN + 3(CH_3CO)_2O \longrightarrow (CH_3CO)_3SiCH_2CH_2CN + 3CH_3COCl, \tag{9}$$

$$Cl_3SiCH_2CH_2CN + 3CH_3CH_2COOK \longrightarrow (CH_3CH_2COO)_3SiCH_2CH_2CN + 3KCl. \tag{10}$$
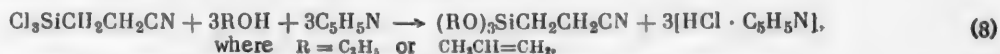
EXPERIMENTAL

Starting materials. Chloromethyldimethylchlorosilane, chloromethyltrimethylsilane, and chloromethyl-dimethylethylsilane were prepared by known methods [15-17]. Iodomethyltrimethylsilane was prepared by Grignard synthesis from 1.45 moles of methyl iodide, 1.25 moles of magnesium, and 0.90 mole of chloromethyl-dimethylchlorosilane, after which the ether was distilled off and the reaction mixture heated for 15 hours at 98-103°; yield 53%, b. p. 137-141°. Literature data [13]: b. p. 139.5° (750 mm). Iodomethyldimethylethyl-silane was similarly obtained in 69% yield, b. p. 168-169° (752 mm). According to cited data [13], b. p. 169.5° (763 mm).

β-Cyanoethyltrimethylsilane from iodomethyltrimethylsilane. The reaction was carried out in a four-neck, thick-walled flask provided with stirrer, oil seal, reflux condenser and drying tube, thermometer, and dropping funnel. The flask was charged with 62 g (0.28 mole) of iodomethyltrimethylsilane and 28.7 g (0.7 mole) of dried and freshly distilled acetonitrile in 200 ml of dry ether, and several pieces of sodium out of a weighed quantity of 11.6 g (0.5 mole) were added. The reaction began immediately (precipitate, gas evolution), after which the rest of the sodium was added during 2.5 hours, with efficient stirring. The reaction mixture was boiled and stirred for 8 more hours; then part of the ether was distilled off and the contents of the flask stirred at 45-55° for another 6 hours. After cooling, the pulpy mass was cautiously decomposed by water and extracted several times with ether. The ether extracts were dried over calcium chloride, the ether driven off, and the residue distilled in vacuo; 19.3 g of β-cyanoethyltrimethylsilane was obtained; yield 52%, reckoned on the basis of the iodide taken for reaction.

B. p. 74-75° (25 mm), n_D^{20} 1.4236, d_4^{20} 0.8275.

Literature data: 67-67.5° (17 mm), n_D^{20} 1.4240, d_4^{20} 0.8277 [2], 94° (49 mm), n_D^{20} 1.4240, d_4^{20} 0.8270 [1, 6].

β-Cyanoethyltrimethylsilane from chloromethyltrimethylsilane. In the experiment 25 g (0.204 mole) of chloromethyltrimethylsilane, 25 g (0.61 mole) of acetonitrile, 2 g of dry sodium iodide, 7.5 g (0.32 mole) of sodium, and 200 ml of ether were used. Addition of several pieces of sodium to the reaction mixture did not hasten the beginning of the reaction; the latter commenced only after the materials were heated for 1.5 hours. The reaction mixture was stirred for 5 hours under reflux and 12 hours at 45-55°. β-Cyanoethyltrimethylsilane was isolated by threefold distillation in 19% yield, b. p. 63-66° (15 mm), n_D^{20} 1.4252.

β-Cyanoethylethyldimethylsilane from iodomethylethyldimethylsilane was prepared from 20.5 g of acetonitrile, 7.4 g of sodium, and 45.5 g of iodomethylethyldimethylsilane; yield 28%.

B. p. 92-94° (22 mm), $n^{20}D$ 1.4335, d^{20}_4 0.8440, MR_D 43.55; calc. 43.85 [18].

β-Cyanoethylethyldimethylsilane from chloromethylethyldimethylsilane. A 12.4 g quantity of sodium, 250 ml of dry o-xylene, and 26 g of acetonitrile were heated to 80-85°; at this temperature the exothermic reaction of formation of the organosodium derivative began. When the reaction mixture had cooled, 4.5 g of dry sodium iodide and 50 g of chloromethylethyldimethylsilane were added to the flask. After the appropriate treatment β-cyanoethylethyldimethylsilane was obtained in 11.5% yield.

B. p. 93-94° (22 mm), $n^{20}D$ 1.4335, d^{20}_4 0.8416, MR_D 43.66; calc. 43.85 [18].

Found %: C 58.94, 59.15; H 10.99, 10.84. $C_7H_{15}NSi$. Calculated %: C 59.52; H 10.70.

β-Trimethylsilylpropiophenone $(CH_3)_3SiCH_2CH_2COC_6H_5$. To the Grignard reagent, prepared from 28.2 g (0.18 mole) of freshly distilled bromobenzene and 4.55 g (0.19 mole) of magnesium in 200 ml of ether, was added 16.5 g (0.13 mole) of β-cyanoethyltrimethylsilane during 15 minutes. The contents of the flask were stirred for 3 hours at room temperature and on the following day, boiled for 5 hours. After the usual treatment there was obtained 19 g of crude β-trimethylsilylpropiophenone, b. p. 136-143° (15 mm), which after redistillation had the constants:

B. p. 140° (15 mm), $n^{20}D$ 1.5199, d^{20}_4 0.9521, MR_D 64.88, calc. 63.71 [18]. With correction [19] for silicon-containing ketones of the type $(CH_3)_3SiCH_2C_6H_4COR$ (R = alkyl) MR_D calc. 65.71. Yield 71%, reckoned on the basis of the $(CH_3)_3SiCH_2CH_2CN$ taken for reaction.

Found %: C 70.57, 70.48; H 8.78, 8.93; Si 12.95, 13.03. $C_{12}H_{18}OSi$. Calculated %: C 69.85; H 8.79; Si 13.60.

The 2,4-dinitrophenylhydrazone of this ketone was obtained by the cited method [20]; m. p. 186.5°.

Found %: N 15.36, 15.34. $C_{18}H_{22}O_4N_4Si$. Calculated %: N 15.45.

β-Trimethylsilylethyl methyl ketone was similarly obtained.

B. p. 82-83° (65 mm), $n^{20}D$ 1.4239.

Literature data: b. p. 81.5-83° (64 mm), $n^{20}D$ 1.4235 [2]; 84° (65 mm), $n^{20}D$ 1.4228 [14].

β-Trimethylsilylethylmethylphenylcarbinol $(CH_3)_3SiCH_2CH_2C(CH_3)(C_6H_5)OH$. To the Grignard reagent, prepared from 2.4 g (0.1 mole) of magnesium and 15.7 g (0.1 mole) of freshly distilled bromobenzene in 100 ml of ether, was added 11.5 g (0.08 mole) of β-trimethylsilylethyl methyl ketone, with stirring. The contents of the flask were heated in a water bath for 3 hours and decomposed by water. After the usual treatment there was obtained 13.8 g of the carbinol, yield 78%.

B. p. 102-102.5° (2 mm), $n^{20}D$ 1.5038, d^{20}_4 0.9463, MR_D 69.50; calc. 69.96 [18].

Found %: C 69.80, 70.10; H 9.34, 9.47; Si 12.25, 12.64. $C_{13}H_{22}OSi$. Calculated %: C 70.25; H 9.97; Si 12.62.

β-Cyanoethyltriethoxysilane. To 18.8 g (0.1 mole) of β-cyanoethyltrichlorosilane and 24 g (0.3 mole) of pyridine in 200 ml of anhydrous benzene was added, with stirring, 13.8 g (0.3 mole) of anhydrous alcohol at a rate of 3-5 drops per minute, after which the reaction mixture was stirred for 3 hours and left overnight. On the next day the precipitate was filtered out and washed with 50 ml of benzene. After the benzene was distilled from the filtrate, the heavy oil was cooled, further freed from newly formed precipitate, and distilled in vacuo. Yield 62%.

B. p. 100-100.5° (6 mm), $n^{20}D$ 1.4140, d^{20}_4 0.9792, MR_D 55.56; calc. 55.47 [18].

Found %: Si 12.65, 12.80. $C_9H_{19}O_3NSi$. Calculated %: Si 12.91.

β-Cyanoethyltriallyloxysilane. From 27 g (0.143 mole) of β-cyanoethyltrichlorosilane, 34 g (0.43 mole) of pyridine, and 25 g (0.43 mole) of anhydrous, freshly distilled allyl alcohol in 300 ml of benzene there was obtained 19.5 g of a substance having b. p. 135-142° (4 mm) with slight decomposition. Pure β-cyanoethyltriallyloxysilane was obtained after redistillation; yield 54.5%.

B. p. 136° (4 mm), $n^{20}D$ 1.4506, d^{20}_4 1.0073, MR_D 67.67; Calc. 68.01 [18].

Found %: N 5.25, 5.42. $C_{12}H_{19}O_3NSi$. Calculated %: N 5.52.

β-Cyanoethyltriacetoxysilane. A flask provided with a reflux condenser was charged with 10.8 g (0.58 mole) of β-cyanoethyltrichlorosilane and 17.8 g (0.174 mole) of freshly distilled acetic anhydride. As the reagents merged, the reaction mixture grew warm; after cooling, the contents of the flask were boiled for 9 hours, the acetyl chloride driven off, and the residue distilled in vacuo. There was obtained 14.5 g of crystalline β-cyanoethyltriacetoxysilane; yield 97.5%; b. p. 136.5° (2 mm), m. p. 43-43.5° (in a sealed capillary).

Found %: Si 11.26, 10.73. $C_9H_{13}O_6NSi$. Calculated %: Si 10.82.

β-Cyanoethyltripropionoxysilane. A mixture of 10.8 g (0.058 mole) of β-cyanoethyltrichlorosilane, 29 g (0.25 mole) of potassium propionate (thoroughly dried), and 200 ml of freshly distilled petroleum ether (b. p. 90-95°) was heated and stirred for 9 hours. The precipitate was filtered out and washed with 50 ml of petroleum ether. After the solvent was driven off and the residue distilled in vacuo, there was obtained 3.5 g of a liquid with b. p. 172-173° (1.5 mm) (decomp.), yield 20%.

B. p. 162-163° (1 mm) (decomp.), $n^{20}D$ 1.4342, d^{20}_4 1.1243, MR_D 69.82; calc. 69.42 [18].

Found %: Si 9.48, 9.24. $C_{12}H_{19}O_6NSi$. Calculated %: Si 9.31.

SUMMARY

A method of preparation of β-cyanoethyltrialkylsilanes by condensation of α-halomethyltrialkylsilanes with acetonitrile, using sodium, is proposed.

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THIAZOLIDINE-4-CARBOXYLIC ACID AND ITS DERIVATIVES

VIII. ON THE CONDENSATION OF CYSTEINE WITH AN ESTER OF α-FORMYL-β-PHENYLPROPIONIC ACID, AND ITS DERIVATIVES

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As is generally known, thiazolidine-4-carboxylic acid and its derivatives are unstable compounds and partially decompose on treatment with water to β-mercapto-α-amino acids and aldehydes, thus forming two compounds with new functional groups [1-3]. We were primarily interested in the compounds obtained by condensation of L-cysteine with esters of α-formyl-β-phenylpropionic and α-formyl-β-(p-hydroxyphenyl)propionic acids.

Ethyl β-phenylpropionate was prepared from β-phenylpropionic acid [4]. Auwers [5] established that when ethyl β-phenylpropionate reacts with ethyl formate in an ether medium in the presence of sodium, the formyl group goes to the α-position; this was proved by the conversion of ethyl α-formyl-β-phenylpropionate to indene-β-carboxylic acid. Thus, there was no doubt as to the position of the formyl group in compounds (II) and (VI).

On condensation of L-cysteine (I) with ethyl α-formyl-β-phenylpropionate (II), ethyl α-benzyl-α-(4-carboxythiazolidyl-2)-acetate (III) is readily formed.
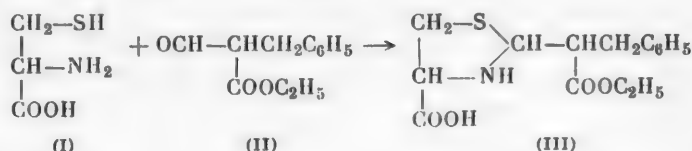
The synthesis of a compound with a hydroxyl group in the para-position of the benzene ring (VIII) was carried out according to the following scheme: β-(p-hydroxyphenyl)propionic acid was converted to the methyl ester (IV) [6], and then methyl β-(p-benzoxyphenyl)propionate (V) was prepared from the latter with the aid of sodium ethoxide and benzyl chloride. The formyl group was introduced by condensation of compound (V) with ethyl formate in the presence of sodium. Methyl β-(p-benzoxyphenyl)-α-formylpropionate (VI) was condensed with L-cysteine hydrochloride. The benzyl group in methyl α-(p-benzoxybenzyl)-α-(4-carboxythiazolidyl-2)-acetate (VII) was split out by shaking with concentrated hydrochloric acid at room temperature.

$$\begin{array}{l} \text{CH}_2\text{—S} \\ \quad\quad\quad\;\;\diagdown \;\;\text{CHClCH}_2\text{C}_6\text{H}_4\text{OH} \\ \text{CH—NH} \quad\; | \\ \quad | \quad\quad\quad\;\text{COOCH}_3 \\ \text{COOH} \end{array}$$
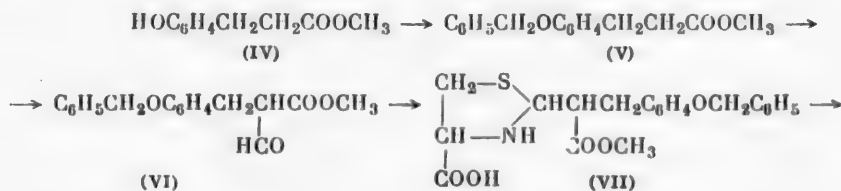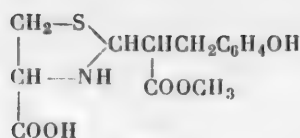
(VIII)

EXPERIMENTAL

Ethyl α-benzyl-α-(4-carboxythiazolidyl-2)-acetate (III). Into a 100 ml round-bottom flask provided with stirrer, thermometer, and reflux condenser were put 3.15 g of L-cysteine hydrochloride and 25 ml of water. With stirring, 1.6 g of sodium bicarbonate was gradually added, followed by 25 ml of alcohol and 4 g of ethyl α-formyl-β-phenylpropionate (II). The flask was heated in a water bath at 80° for 2 hours. On cooling, the reaction mass was poured into 100 ml of water and extracted three times with 100 ml of ether. Compound (III) was extracted from the ethereal solution with 5% sodium bicarbonate solution. On acidification of the aqueous solution a thick oil separated out, which quickly crystallized. There was obtained 3.1 g (about 50%). For analysis the substance was recrystallized twice from a little anhydrous alcohol. M. p. 113-114°.

Found %: C 58.01; H 6.16; N 4.52, 4.53. $C_{15}H_{19}O_4NS$. Calculated %: C 58.24; H 6.19; N 4.52.

Methyl β-(p-benzoxyphenyl)propionate (V). Into a 250 ml flask, coupled with a reflux condenser which was closed with a calcium-chloride tube, were put 120 ml of anhydrous methanol and 4 g of sodium, after which 28.75 g of methyl β-(p-hydroxyphenyl)propionate and 24 g of benzyl chloride were added. The mixture was heated for 50 hours. The solution was filtered while hot to remove sodium chloride, the methanol was distilled off in vacuo, and the remaining oil was treated with 300 ml of ether. The ethereal solution was washed with water and dried with magnesium sulfate, the ether was driven off, and the remaining oil was fractionated in vacuo; in this case the fraction boiling at 198-203° (2 mm) was collected. Yield 24 g (55.6%). A thick, colorless oil.

Found %: C 75.67; H 6.84. $C_{17}H_{18}O_3$. Calculated %: C 75.53; H 6.72.

Methyl α-formyl-β-(p-benzoxyphenyl)propionate (VI). Into a 250 ml round-bottom flask provided with stirrer and reflux condenser were put 100 g of dry ether, 24 g of methyl β-(p-benzoxyphenyl)propionate, and 7.5 g of ethyl formate; then 2.1 g of sodium, cut into thin sheets, was added. The mass was stirred for 7 hours. A white precipitate gradually formed. Ten ml of methanol was added in order to eliminate the unreacted sodium, and the mixture was stirred for 3 more hours. The reaction mass was then treated with 300 ml of water, and the water layer was separated, washed with ether, and acidified with hydrochloric acid. The oil, which separated out, was extracted with ether and the ethereal solution dried with magnesium sulfate. The ether was distilled off. The remaining oil crystallized. Yield 12.8 g (50.6%). For analysis the substance was recrystallized twice from a toluene-petroleum ether mixture. M. p. 98-100°.

Found %: C 71.97; H 6.31. $C_{18}H_{18}O_4$. Calculated %: C 72.47; H 6.08.

From the main ethereal solution, 10.7 g of unreacted methyl β-(p-benzoxyphenyl)propionate was recovered.

Methyl α-(p-benzoxybenzyl)-α-(4-carboxythiazolidyl-2)-acetate (VII). A 4.5 g quantity of L-cysteine hydrochloride, 8 g of methyl α-formyl-β-(p-benzoxyphenyl)propionate, and 20 ml of alcohol were heated at 80° for 1 hour. On cooling, the reaction mass was diluted with water, the aqueous solution was made weakly acid (to Congo), and the oil, which separated out, was extracted with 150 ml of ether. To eliminate impurities, the ethereal solution was treated with 5% sodium bicarbonate solution, and the latter was separated from the ether layer and acidified with aqueous hydrochloric acid solution, after which the oil, which separated out, was again extracted with ether. The ethereal solution was dried with magnesium sulfate and concentrated to a volume of 15 ml. On cooling of the ether solution 6.15 g (91%) of the substance was isolated. For analysis the substance was recrystallized from ether. Colorless crystals. M. p. 89-91°.

Found %: C 63.05; H 5.93; N 3.56. $C_{21}H_{23}O_5NS$. Calculated %: C 62.83; H 5.77; N 3.48.

Methyl α-(p-hydroxybenzyl)-α-(4-carboxythiazolidyl-2)-acetate (VIII). Five g of methyl α-(p-benzoxy-benzyl)-α-(4-carboxythiazolidyl-2)-acetate was shaken in a bottle with 50 ml of concentrated hydrochloric acid and 10 ml of ether for 5 days, the substance dissolving completely; the solution was diluted with 100 ml of water and washed with 50 ml of ether. The water layer was drawn off, neutralized with ammonia to pH 3, treated with charcoal at room temperature, and filtered. A primer was added to the clear solution. On slow evaporation of the water in vacuo to a volume of 50 ml, crystals separated. They were filtered out, washed with water, and for analysis, recrystallized twice from methanol. Yield 1 g. M. p. 161-162°.

Found %: C 54.25; H 5.54; N 4.52; S 9.89. $C_{14}H_{17}O_5NS$. Calculated %: C 54.01; H 5.50; N 4.47; S 10.31.

Compounds (III), (VII), and (VIII) were cleaved by heating with 1 N sodium hydroxide solution for 1 minute, after which the solution gave the nitroprusside reaction for the mercapto group. Furthermore, they were easily oxidized by iodine solution.

SUMMARY

Esters of α-benzyl-α-(4-carboxythiazolidyl-2)-acetic acid and $\dot{\alpha}$-(p-hydroxybenzyl)-α-(4-carboxy-thiazolidyl-2)-acetic acid have been prepared.

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AMINOACYL DERIVATIVES OF NUCLEOSIDES

V. SYNTHESIS OF N^6-AMINOACYL AND N^6-PEPTIDE DERIVATIVES OF CYTIDINE

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In the preceding paper [1] methods of synthesizing N^6-aminoacyl and N^6-peptide derivatives of a cytidine analog — 3-β-D-tetraacetylglucopyranosylcytosine — were described. The nucleoside differed from natural cytidine (3-β-D-ribofuranosylcytosine) in the structure of the sugar. In the present work the cytidine, entering into the composition of ribonucleic acid, and its N^6-aminoacyl and N^6-peptide derivatives were synthesized.

The most convenient method of synthesis of cytidine is the modification of the Hilbert-Johnson method, recently proposed by Fox and co-workers [2], which consists in the condensation of 1-chloro-2,3,5-tri-O-benzoyl-D-ribose with chloromercuri-6-ethoxypyrimidone-2, followed by amination. In order to carry out this synthesis, 1-O-acetyl-2,3,5-tri-O-benzoyl-D-ribose was prepared. Pure D-ribonolactone was obtained from technical D-ribonolactone through Cd ribonate [3]. The pure lactone was reduced [4] to D-ribose, which was isolated in the form of a sirup. The sirup, containing 60% D-ribose, was benzoylated, after which the benzoyl radical attached to C_1 was replaced by acetyl [5]. 1-O-Acetyl-2,3,5-tri-O-benzoyl-D-ribose was halogenated by an ethereal hydrogen chloride solution saturated at 0° [2], and brought into reaction with chloromercuri-6-ethoxypyrimidone-2 [2]. Cytidine was obtained in the form of the sulfate in 50% yield. The constants of the synthesized cytidine sulfate agreed with those given in the literature.

The most convenient method of synthesis of N^6-aminoacyl and N^6-peptide derivatives of the cytosine nucleoside, as we showed earlier [1], is the "carbodiimide" method. The use of this method for the synthesis of aminoacyl derivatives of cytidine made it possible to employ a nucleoside of a sugar containing unsubstituted hydroxyl groups in this reaction, since hydroxyl groups are not aminoacylated under these conditions [6].
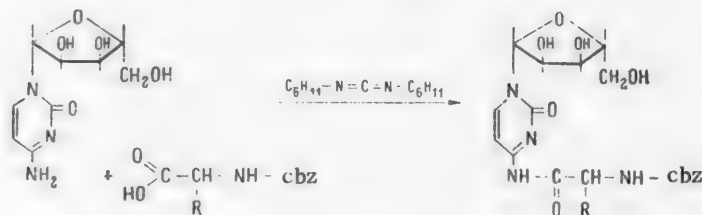
Constants and yields of the synthesized N^6-monoaminoacyl, N^6-dipeptide, and N^6-tripeptide derivatives of cytidine are given in Table 1.

In this way, acylation of cytidine by carbobenzoxyphenylalanine gave carbobenzoxyphenylalanylcytidine in 90% yield. Since the UV absorption spectrum of this compound is similar to that of N^6-carbobenzoxy-phenylalanyl-3-β-D-tetraacetylglucopyranosylcytosine, the structure of which is established [7], it may be considered that cytidine also is aminoacylated in the amino group, a N^6-aminoacylcytidine being formed.

In this way we obtained, in good yields, N^6-aminoacyl and N^6-peptide derivatives of cytidine with various amino acids (serine, tyrosine, cysteine, lysine) containing both α-amino and other functional groups.

TABLE 1

N^6-Aminoacyl and N^6-Peptide Derivatives of Cytidine (3-β-D-Ribofuranosylcytosine)
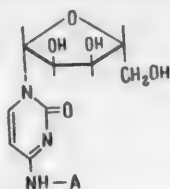
A	Formula	Yield (in %)	M. p. (decomp)	Absorption in UV (95% C_2H_5OH)		% N	
				λ max (in mμ)	ε	found	calc.
Carbobenzoxy-phenylalanine*	$C_{26}H_{28}O_8N_4 \cdot 2H_2O$	90	114—118°	250, 300	9240, 4480	9.99	10.00
Dicarbobenzo xytyrosine	$C_{34}H_{34}O_{10}N_4 \cdot 2H_2O$	50	82—85	250, 300	6640, 3160	7.92	8.05
Dicarbobenzoxylysine	$C_{31}H_{37}O_{10}N_5 \cdot 2H_2O$	35	75—77	250, 300	4243, 1620	10.30	10.37
Dicarbobenzoxyserine	$C_{28}H_{30}O_{10}N_4 \cdot 2H_2O$	31	92—94	250, 300	2740, 1489	9.10	9.00
Carbobenzoxy-phenylalanyl-S-benzylcysteine**	$C_{36}H_{39}O_9N_5S \cdot 2H_2O$	41	88—90	250, 300	4243, 1620	—	
Carbobenzoxyvalyl-phenylalanine	$C_{31}H_{37}O_9N_5 \cdot 2H_2O$	46	91—93	250, 300	2990, 2350	10.56	10.60
Carbobenzoxyvalyl-phenylalanyl-phenylalanine	$C_{40}H_{46}O_{10}N_6 \cdot 2H_2O$	34	115—117	250, 300	2514, 2620	10.44	10.42

* Found %: C 55.41; H 5.83. Calculated %: C 55.8; H 5.71.
** Found %: C 55.9; H 5.76. Calculated %: C 55.76; H 5.71.

Aminoacyl derivatives of 3-β-D-glucopyranosylcytosine, in which the hydroxyl groups of the sugar also remained open, were similarly obtained. The yields and constants of N^6-aminoacyl and N^6-peptide derivatives of 3-β-D-glucopyranosylcytosine are given in Table 2.

Various N^6-aminoacyl derivatives of cytosine nucleosides, which differed among themselves either in the structure of the amino acid forming the amide bond or in that of the sugar, being available, it was of interest to find out the effect of these components on the hydrolytic stability of the amide bond. For this the synthesized compounds were hydrolyzed at 100° with water, alkali, and acid. The course of the hydrolysis was followed spectrophotometrically by the method which we described earlier [7]. In Table 3 are given the results of hydrolysis of N^6-aminoacyl derivatives of cytidine and 3-β-D-glucopyranosylcytosine, containing identical amino acids and peptides. For comparison, data on the hydrolytic stability of the amide bond in N^6-aminoacyl-3-β-D-tetraacetylglucopyranosylcytosines also are given in certain cases.

It follows from the data on the hydrolytic stability of the amide bond in N^6-aminoacyl and N^6-peptide derivatives of cytidine and 3-β-D-glucopyranosylcytosine, given in Table 3, that: 1) the amide bond is hydrolyzed with difficulty by boiling water; the structure of the carbohydrate, entering into the composition of the nucleoside, has a considerable effect on the stability of the amide bond; in N^6-aminoacyl-3-β-D-glucopyranosylcytosines the amide bond is more stable than in the corresponding cytidine derivatives; the character of the amino acid or peptide radical also has appreciable influence; 2) the amide bond is much more easily hydrolyzed by 0.1 N NaOH or 0.1 N HCl (100°); in this case the influence of the character of the carbohydrate and the aminoacyl radical appears weaker.

TABLE 2

N^6-Aminoacyl and N^6-Peptide Derivatives of 3-β-D-Glucopyranosylcytosine
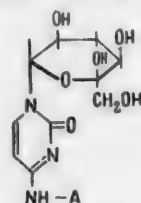
A	Formula	Yield (in %)	M. p. (dec)	Absorption in UV (95% C_2H_5OH)		% N	
				λ_{max} (in mμ)	ε	found	calc.
Carbobenzoxy-phenylalanine*	$C_{27}H_{30}O_9N_4 \cdot 2H_2O$	76	89—92°	250, 300	3420, 1320	9.40	9.49
Dicarbobenzo-xytyrosine	$C_{35}H_{36}O_{11}N_4 \cdot 2H_2O$	43	74—76	250, 300	8990, 2370	7.60	7.75
Dicarbobenzoxylysine	$C_{32}H_{30}O_{11}N_5 \cdot 2H_2O$	60	81—83	250, 300	5857, 2270	9.84	9.92
Dicarbobenzoxyserine	$C_{29}H_{32}O_{11}N_4 \cdot 2H_2O$	34	82—84	250, 300	4870, 2310	8.56	8.64
Carbobenzoxyphenyl-alanyl-S-benzyl-cysteine	$C_{37}H_{41}O_{10}N_5S \cdot 2H_2O$	47	105—108	250, 300	3890, 1500	8.83	8.93

* Found %: C 54.87; H 5.66. Calculated %: C 54.91; H 5.76.

TABLE 3

Time (in Minutes) Required for Complete Hydrolysis of the Amide Bond in N^6-Aminoacyl and N^6-Peptide Derivatives of Cytidine and 3-β-D-Glucopyranosylcytosine

No.	Carbobenzoxyamino acid or carbobenzoxy peptide, linked with the nucleoside	Cytidine			3-β-D-Glucopyranosylcytosine		
		hydrolytic agent			hydrolytic agent		
		H_2O	0.1 N. NaOH	0.1 N. HCl	H_2O	0.1 N NaOH	0.1 N. HCl
1	Phenylalanine	180	30	15	Not hydrolyzed after 25 hours	45	15
					Not hydrolyzed after 50 hours *	80 *	15 *
2	Tyrosine	60	30	10	120	60	30
3	Serine	600	40	30	900	60	80
4	Lysine	900	15	5	Not hydrolyzed after 25 hours	30	5
5	Valylphenylalanine	420	50	60	Not hydrolyzed after 25 hours *	50 *	60 *
6	Phenylalanyl	300	60	60	420	80	60
7	Valylphenylalanyl-phenylalanine	900	360	90	Not hydrolyzed after 25 hours	360	120

* Data given for the N^6-aminoacyl-3-β-D-tetraacetylglucopyranosylcytosine.

The compounds obtained were also hydrolyzed by means of crystalline chymotrypsin. Assuming that the hydrolysis consists solely in cleavage of the amide bond with formation of the free cytosine nucleoside and the carbobenzoxyamino acid (or carbobenzoxypeptide), we decided to follow the course of the hydrolysis by the method of paper chromatography. The hydrolyzates were chromatographed in the system isoamyl alcohol − 5% Na_2HPO_4 [8]. When chromatographed in this system, aminoacyl derivatives of cytidine and 3-β-D-gluco-pyranosylcytosine move with the solvent front, cytidine has $R_f = 0.76$, and 3-β-D-glucopyranosylcytosine has $R_f = 0.86$. Chromatographic investigation of the hydrolyzates showed that all the compounds listed in Tables 1 and 2, with the exception of cysteine derivatives of cytidine and 3-β-D-glucopyranosylcytosine, are very easily hydrolyzed (15 minutes) by chymotrypsin. The amide bond in N^6-carbobenzoxyphenylalanyl-S-benzylcysteyl-cytidine and the corresponding 3-β-D-glucopyranosylcytosine derivative is not hydrolyzed by chymotrypsin on heating (37°) for 4 hours.

EXPERIMENTAL

1. Cytidine (3-β-D-ribofuranosylcytosine). Cytidine was synthesized by the method of Fox and co-workers [2] from chloromercuri-6-ethoxypyrimidone-2 and 1-chloro-2,3,5-tri-O-benzoyl-D-ribose. The 1-O-acetyl-2,3,5-tri-O-benzoyl-D-ribose required for the synthesis was prepared by acylation of ribose* according to Kissman [5], in 60% yield. Cytidine was isolated in the form of the sulfate, m. p. 222-223°; $R_f = 0.76$ in the system isoamyl alcohol − 5% Na_2HPO_4 solution. Absorption in UV (95% C_2H_5OH): λ_{max} 273 mμ (ε 8970).

2. N^6-Carbobenzoxyphenylalanylcytidine. To a solution of 0.09 g of carbobenzoxyphenylalanine in 3 ml of dioxane were added a solution of 0.082 g of cytidine sulfate in 5 ml of dioxane, 0.25 ml of 1 N NaOH, and 0.065 g of N,N'-dicyclohexylcarbodiimide. The reaction mixture was left for 4 hours at room temperature. The dicyclohexylcarbamide precipitate was filtered off and the solution evaporated in vacuo. The remaining oil was dissolved in 5 ml of chloroform. The chloroform solution was washed with 1 N CH_3COOH solution, water, 2 N soda solution, and again water and dried over $MgSO_4$. To the dry solution was added 15-20 ml of dry petroleum ether. The resulting precipitate was filtered out and washed with petroleum ether. Other N^6-aminoacyl and N^6-peptide derivatives of cytidine and 3-β-D-glucopyranosylcytosine (Tables 1 and 2) were similarly prepared.

3. The hydrolysis of N^6-aminoacyl and N^6-peptide derivatives of cytidine and 3-β-D-glucopyranosyl-cytosine by water, 0.1 N NaOH, and 0.1 N HCl was carried out by the method described earlier [7]. The course of the hydrolysis was followed by measuring the UV absorption of the hydrolyzates in 96% alcohol. The results of hydrolysis are given in Table 3.

4. Hydrolysis of N^6-carbobenzoxyphenylalanylcytidine by chymotrypsin. To a solution of 0.075 g of N^6-carbobenzoxyphenylalanylcytidine in 2 ml of alcohol was added 0.006 g of crystalline chymotrypsin, dissolved in 5 ml of phosphate buffer (pH 7.7). The heterogeneous mixture (pH 7.9) was left in a thermostat (37°) for 4 hours. The following control solutions were put into the thermostat at the same time: 1) 0.075 g of N^6-carbobenzoxyphenylalanylcytidine in 2 ml of alcohol and 5 ml of buffer solution and 2) 0.003 g of chymotrypsin in 2 ml of buffer solution and 1 ml of alcohol. The course of the hydrolysis was followed by means of paper chromatography. After 5, 15, 30, 45, 60, 90, 120, 180, and 240 minutes, samples (0.1 ml) of the hydrolyzate and control solutions were taken and applied to the chromatogram in equal quantities. For control a cytidine solution also was applied. Ascending or descending chromatograms were developed in the system isoamyl alcohol − 5% Na_2HPO_4 solution [8]. After drying, the chromatograms were examined in UV. In the hydrolyzate, which was heated for 15 minutes, a spot was found which corresponded to the distribution coefficient of cytidine ($R_f = 0.76$). With more prolonged hydrolysis the spots corresponding to cytidine became more intense. In the control samples no spots absorbing in UV were observed.** The spot with $R_f = 0.76$ was cut out and eluted with water. The eluate was evaporated and diluted with anhydrous alcohol, and the UV absorption spectrum of the resulting solution was taken. The spectrum fully coincided with the absorption spectrum of cytidine (λ_{max} 273 mμ). Fermentative hydrolysis of all the synthesized N^6-aminoacyl and N^6-peptide derivatives of

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* The ribose that we obtained on reduction of ribonolactone [4] consisted of a sirup with 60% sugar content. The sirup was dried in vacuo and acylated.

** N^6-Carbobenzoxyphenylalanylcytidine moves with the solvent front in this system.

cytidine and 3-β-D-glucopyranosylcytosine was similarly carried out.* Liberation of the nucleoside was observed in all cases except N^6-carbobenzoxyphenylalanyl-S-benzylcysteyl derivatives of cytidine and 3-β-D-gluco-pyranosylcytosine. On hydrolysis of N^6-dicarbobenzoxylysine derivatives of cytidine and 3-β-D-glucopyranosyl-cytosine the nucleoside also appeared in the control sample; this is explained by the great lability of the amide bond in these compounds.

SUMMARY

1. N^6-Aminoacyl and N^6-peptide derivatives of cytidine and 3-β-D-glucopyranosylcytosine were prepared through acylation of the latter substances by means of carbobenzoxyamino acids and carbobenzoxypeptides in the presence of N,N'-dicyclohexylcarbodiimide.

2. The hydrolytic stability of the amide bond in N^6-amino acid and N^6-peptide derivatives of cytidine and 3-β-D-glucopyranosylcytosine with respect to water, 0.1 N NaOH, 0.1 N HCl, and chymotrypsin was studied. The relation between the hydrolytic stability of the amide bond in these compounds and the character of the hydrolytic agent, type of carbohydrate entering into the composition of the nucleoside, and character of the aminoacyl radical was determined.

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* 3-β-D-Glucopyranosylcytosine has $R_f = 0.86$ in this solvent system.
** Original Russian pagination. See C. B. Translation.

THE INTERACTION OF α-OXIDES OF THE ACETYLENIC SERIES WITH DIAMINES. A NEW METHOD OF PREPARATION OF DIPYRROLE

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Aliphatic diamines (ethylenediamine, propylenediamine, hexamethylenediamine, etc.) and aromatic diamines (m- and p-phenylenediamines) react with 1,4-dicarbonyl compounds to form dipyrroles [1]. A very small number of dipyrroles have been prepared up to now on the basis of 1,4-dicarbonyl compounds, these syntheses leading only to 2,5-disubstituted pyrroles. Although it is possible in principle to obtain by this method substituted dipyrroles of any size and order, dicarbonyl compounds of this class have not hitherto been easily accessible. The objective of the present work was the development of a new method of preparation of dipyrroles on the basis of α-oxides of the acetylenic series which would widen the possibilities of synthesis of various dipyrroles.

TABLE 1

Compound No.	Formula and name	Boiling point (pressure in mm)	n_D^{20}	d_4^{20}
(I)	$CH_3-C\equiv C-C(\overset{O}{\diagup})-CH_3$, CH_3 2-Methyl-1,2-epoxy-3-pentyne	40—41° (22)	1.4460	0.9264
(II)	$C_6H_5-C\equiv C-C(\overset{O}{\diagup})-CH_3$, CH_3 2-Methyl-4-phenyl-1,2-epoxy-3-butyne	108—109 (8)	1.5552	1.0278
(III)	$\langle\ \rangle-C\equiv C-C(\overset{O}{\diagup})-CH_3$, CH_3 2-Methyl-4-cyclo-hexenyl-1,2-epoxy-3-butyne	75—76 (0.5)	1.5155	1.1195

The oxides formulated in Table 1 were selected for investigation. A study was made of their reactions with ethylenediamine, hexamethylenediamine, and p-phenylenediamine which may be represented by the scheme

$$2R_1-C\equiv C-\underset{\underset{CH_3}{|}}{C}-\overset{O}{\overset{\triangle}{}}CH_2 + NH_2-R-NH_2 \longrightarrow$$

$$\longrightarrow \left[R_1-C\equiv C-\underset{\underset{CH_3}{|}}{\overset{\overset{OH}{|}}{C}}-CH_2-NH-R-NH-CH_2-\underset{\underset{CH_3}{|}}{\overset{\overset{OH}{|}}{C}}-C\equiv C-R_1 \right] \longrightarrow$$

$$\xrightarrow{-2HOH}$$
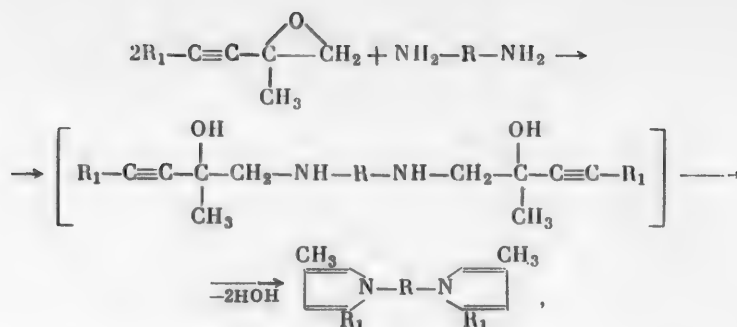
where R is ethylene, hexamethylene, or p-phenylene; R_1 is methyl, phenyl, or cyclohexenyl.

Reaction of oxide (I) with ethylenediamine gave two substances: N-β-aminoethyl-2,4-dimethylpyrrole (IV), which is the product of interaction of the oxide with one amino group of ethylenediamine, and N,N'-(ethylene)-bis-(2,4-dimethylpyrrole) (V) — the product of reaction of the oxide with two NH_2 groups of the diamine. Oxides (II) and (III) react with ethylenediamine to form respectively N,N'-(ethylene)-bis-(2-phenyl-4-methylpyrrole) (VI) and N,N'-(ethylene)-bis-(2-cyclohexenyl-4-methylpyrrole) (VII). Oxide (I) reacts with hexamethylenediamine to give N,N'-(hexamethylene)-bis-(2,4-dimethylpyrrole) (VIII); p-phenylenediamine reacts with oxides (I) and (II) to give respectively N,N'-(p-phenylene)-bis-(2,4-dimethylpyrrole) (IX) and N,N'-(p-phenylene)-bis-(2-phenyl-4-methylpyrrole) (X). The constants of the prepared compounds are set forth in Table 2.

TABLE 2

Compound No.	Formula	Melting point
(IV)		— *
(V)		90° **
(VI)		160
(VII)		128
(VIII)		103
(IX)		126
(X)		199
(XI)		189

* B. p. 74° (2 mm).
** B. p. 115° (2 mm).

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The structures were confirmed by plotting the infrared absorption spectra of six compounds. The spectra were plotted with the help of the IKS-11 spectrophotometer with a NaCl prism in the range of 700 to 2300 cm^{-1}. The monopyrrole (a liquid) was examined in a 12 μ layer, and the remaining compounds in the form of 20% paste in vaseline oil in 12 and 30 μ layers. The spectra afforded conclusive evidence of the pyrrole structure of the synthesized compounds. The majority of the bands of the pyrrole spectrum [2] were found in the spectra of the prepared compounds. The most characteristic frequencies in the pyrrole spectrum are: 728, 1015, 1046, 1076, 1146, 1418, and 1710 cm^{-1}.

TABLE 3

HC——CH HC‖ ‖CH ＼NH／ pyrrole	(IV)	(V)	(VI)	(VII)	(IX)	(X)
—	—	—	698 (оч. с)	—	—	701 (с)
728 (оч. с)	735 (ср)	731 (с)	726 (ср)	730 (ср)	721 (с)	—
—	—	—	—	—	743 (ср)	751 (ср)
—	755 (ср)	—	757 (оч. с)	—	—	—
768 (с)	—	—	775 (оч. с)	773 (ср)	—	760 (с)
—	—	786 (оч. с)	—	—	789 (оч. с)	—
—	—	803 (с)	807 (с)	804 (с)	—	802 (ср)
838 (сл)	843 (оч. с)	—	—	—	—	846 (с)
—	—	—	855 (ср)	—	850 (оч.сл)	—
868 (ср)	865 (оч. с)	864 (сл)	—	—	—	—
—	—	—	922 (ср)	918 (ср)	—	912 (сл)
—	—	985 (ср)	—	—	988 (с)	—
—	—	999 (ср)	—	—	1002 (ср)	—
1015 (оч. с)	—	1020 (сл)	1012 (ср)	1012 (ср)	1019 (ср)	1028 (сл)
1046 (оч. с)	1038 (ш и с)	1044 (ср)	1037 (ср)	1037 (ср)	1039 (ср)	1054 (ср)
1076 (оч. с)	1084 (ср)	1080 (сл)	1078 (ср)	1078 (ср)	—	1072 (ср)
—	—	—	—	—	1112 (оч. с)	—
1146 (с)	1150 (оч. с)	1135 (с)	1151 (с)	1151 (с)	1140 (оч. с)	1162 (ср)
—	1188 (ср)	1183 (оч. с)	—	—	1183 (оч. с)	1189 (ср)
1202 (сл)	—	1202 (оч. с)	1207 (ср)	1207 (ср)	—	1210 (сл)
1237 (ср)	1228 (ср)	1230 (с)	—	—	1230 (с)	—
—	1320 (ср)	1318 (с)	1320 (ср)	1320 (оч. сл)	1321 (оч. с)	1319 (ср)
—	1342 (с)	1340 (оч. с)	—	1355 (ср)	1348 (оч. с)	1352 (с)
—	—	1370 (сл)	1367 (ср)	—	—	1376 (ср)
—	1400 (ср)	—	—	—	1400 (оч. с)	1392 (с)
1418 (сл)	1422 (оч. с)	1411 (оч. с)	1425 (с)	1418 (с)	1425 (оч. с)	—
—	—	1432 (с)	—	—	1444 (оч. с)	1444 (оч. с)
1467 (с)	1460 (ср)	—	—	—	1469 (ср)	1464 (ср)
—	—	—	1497 (ср)	1497 (с)	—	—
—	—	1514 (оч. с)	—	—	—	1514 (оч. с)
1530 (с)	1530 (ср)	1537 (ср)	—	—	1526 (оч. с)	—
—	—	1556 (ср)	1550 (ср)	1550 (сл)	—	1556 (ср)
—	—	1572 (ср)	—	—	1580 (ср)	1576 (ср)
1600 (оч. сл)	—	1615 (сл)	—	—	—	1613 (ср)
—	1635 (с)	—	1627 (ср)	1627 (ср)	—	1632 (сл)
—	—	—	—	—	—	1646 (сл)
—	—	—	—	—	1685 (сл)	1670 (сл)
—	—	—	—	—	—	1695 (сл)
—	—	1698 (ср)	—	—	—	—
1710	—	—	1710 (сл)	1710 (сл)	—	1710 (сл)

Note: с = strong, ср = medium, сл = weak, ш = broad, и = and, оч. = very.

The introduction of a large number of substituents into the pyrrole molecule was bound to influence the molecular vibrations. It is therefore understandable that some bands are shifted and that in some cases one band is replaced by a doublet or even by several bands which are not present in the pyrrole spectrum. Even a first glance reveals a relation between one absorption band or another and the structure of the molecule. For example, the 1000 and 985 cm^{-1} frequencies are present in the spectra of dipyrroles containing 2 methyls in the ring (this applies both to ethylenedipyrrole and phenylenedipyrrole). These bands do not appear in the case of compounds with a cyclic radical in the ring (phenyl or cyclohexenyl) either in the case of ethylenedipyrrole or of phenylene-dipyrrole; instead this group of compounds exhibits the 920 cm^{-1} frequency. The 1237 cm^{-1} frequency,

characteristic of unsubstituted pyrrole, is present in dimethyl derivatives but absent from all of the compounds with a cyclic radical in the ring (Table 3).

EXPERIMENTAL

Reaction of oxide (I) with ethylenediamine. Into a flask with a ground glass stopper were charged 15 g oxide, 5.7 g ethylenediamine (20% aqueous solution), and 20 ml methanol as solvent. A fair amount of heat was released when the mixture was shaken and a homogeneous liquid was formed; the water and methanol were taken off at 50° in a CO_2 stream (in a 25-30 mm vacuum), and the residue was distilled at 1-2 mm. There was obtained 5 g of (IV) and 6 g of (V). Total yield 70%.

Compound (IV) is a colorless, easily mobile liquid.

d^{20}_4 0.966, $n^{20}D$ 1.5120, MR_D 43.00; calc. 43.37.

Found %: N 20.26; C 69.43; H 10.36; H_{act} 1.04. $C_8H_{14}N_2$. Calculated %: N 20.26; C 69.47; H 10.13; H_{act} 1.00.

It gives the precipitation reaction with mercuric chloride characteristic of pyrrole. The mercury derivative is white and melts at 112° with decomposition. With picric acid it forms a picrate — orange crystals with m. p. 145°.

Compound (V) is in the form of white crystals. It crystallizes in long needles from aqueous alcohol. It sublimes in vacuo and is stable in air and light.

Found %: N 12.93; C 77.17; H 9.44. $C_{14}H_{20}N_2$. Calculated %: N 12.99; C 77.73; H 9.24.

It forms a yellow mercury derivative which melts with decomposition at 86°.

Preparation of dye (XI). 1 g of dipyrrole (V) in alcoholic solution was added to 1 g of phenyldiazonium chloride solution. The resulting precipitate was recrystallized from gasoline to form small orange needles with m. p. 89°.

Found %: N 19.75; C 73.85; H 6.97. $C_{26}H_{28}N_6$. Calculated %: N 19.79; C 73.55; H 6.65.

Dipyrrole (VI). 10 g oxide (II), 1.26 g ethylenediamine (6 ml of 20% aqueous solution) and 12 ml methanol were heated 10 hours at 100° in a sealed glass tube. Crystals came down on cooling. After removal of the alcohol by distillation, the product was recrystallized from aqueous alcohol to form white needles. Yield 8.5 g (80%).

Found %: N 8.28; C 84.20; H 7.38. $C_{24}H_{24}N_2$. Calculated %: N 8.23; C 84.70; H 7.06.

Dipyrrole (VII). 10 g oxide (III) and 1.85 g ethylenediamine were reacted to give 7.5 g of (VII) which was recrystallized from aqueous alcohol to form colorless granules. Yield 70%.

Found %: N 8.03. $C_{24}H_{32}N_2$. Calculated %: N 8.02.

Dipyrrole (VIII). 10 g oxide (I) and 6 g hexamethylenediamine reacted to give 9.5 g of (VIII); recrystallizes from ether as light-yellow plates.

Found %: N 10.45. $C_{18}H_{28}N_2$. Calculated %: N 10.29.

Dipyrroles (IX) and (X). Interaction of oxides (I) and (II) with p-phenylenediamine necessitates heating for 40 hours at 100° since p-phenylenediamine is very much less reactive than ethylenediamine. 5.6 g p-phenylenediamine and 10 g oxide (I) gave 9.6 g (70%) of (IX). Colorless plates with a mother-of-pearl sheen.

Found %: N 10.63; C 81.87; H 7.70. $C_{18}H_{20}N_2$. Calculated %: N 10.60; C 81.80; H 7.62.

3.5 g p-phenylenediamine and 10 g oxide (II) gave 8.4 g (70%) of (X). Small, light-grey, lustrous needles.

Found %: N 7.16; C 86.20; H 6.40. $C_{28}H_{24}N_2$. Calculated %: N 7.21; C 86.59; H 6.18.

SUMMARY

A new method for preparation of dipyrroles was developed on the basis of reaction of α-oxides of the acetylenic series with diamines.

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CONTRAPOLARIZED SYSTEMS AND COLOR CHARACTERISTICS

III. THE EFFECT OF REPLACEMENT OF THE CH$_2$NH GROUP BY THE CH$_2$CH$_2$NH GROUP AND OF METHYLATION OF NH IN COMPOUNDS OF THE STRUCTURE p'-O$_2$NC$_6$H$_4$(CH$_2$)$_n$NHC$_6$H$_4$A-p

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Laboratory of Dye Chemistry and of Color Problems

In the preceding communication [1] we described the color characteristics in the solid state of derivatives of N-[β-(4'-nitrophenyl)-ethyl]-aniline of the general formula (I)
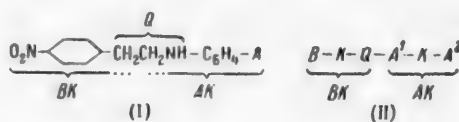
where A = CH$_3$, OCH$_3$, OH, NHCOCH$_3$ and NH$_2$ in the para- or meta-position to the NH group. These compounds are of the type with two separated chromophoric systems BK and AK with a "consecutively linked system K" whose structure corresponds to (II) [2-4] where A' = NH is the first electron-donating chromophoric component [5] of the system AK, and A^2 is the second electron-donating chromophoric component.

It has been established [1] that the introduction of a second electron-donating chromophoric group A into the para- and meta-position gives a bathochromic effect, but in the para-position to the NH this effect is stronger than in the meta-position to A. Direct endomolecular interaction of A with NO$_2$ along the chain is impossible due to the presence between systems BK and AK of group Q =CH$_2$CH$_2$NH which interrupts the conjugation. The development of the color of the compounds in the solid state was attributed to exomolecular [4] interaction of the complex chromophoric systems, namely of two oppositely polarized cochromophores [5] with the electron-accepting BK and the electron-donating AK.

The stronger bathochromic effect of A^2 in the para-position (IV) in comparison with (III) was accounted for by increased electron-donating activity toward the chromophoric system AK (III) due to the contrapolarizing activity of A^2 (two-donor contrasystem A^{1}KA^2), as illustrated by (IV).
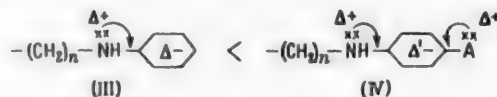
If this explanation is correct, then any increase in electron-donating activity caused by any other means should also bring about a similar deepening of color. Two means of increasing the electron-donating activity of the system AK in (III) and (IV) are considered below: alkylation of NH (conversion of NH to NR) (Examples 1 and 2) and increase of the value of n (number of CH$_2$ groups) as exemplified by the transition from a compound with Q=CH$_2$NH to one with Q =CH$_2$CH$_2$NH (Example 3).

1. Introduction of alkyl into the CH_2CH_2NH group of compounds of type (I). The electron-donating activity can be enhanced by alkylation of the NH group. Amino groups are arranged in the following order in respect to electron-donating activity and in respect to the bathochromic influence (see, for example, [6]):

$$NHCOCH_3 < NH_2 < NHCH_3 < NHCH_2CH_3 < N(CH_3)_2 < N(C_2H_5)_2$$

It can therefore be expected that an alteration in the structure of (I) by alkylation of the NH in the Q group will lead to a bathochromic effect similar to the action of an electron-donating group A in the para-position to the NH. The color intensification should be in the following order:

$$CH_2CH_2NH < CH_2CH_2N(CH_3) < CH_2CH_2N(C_2H_5).$$

With the aim of checking this hypothesis, compounds 2, 4, and 6 were synthesized. In these the hydrogen of the NH group was replaced by a CH_3 group. The visible color and the absorption spectra of the powder surface (based on the percent reflection of light) (Fig. 1) * confirmed these predictions. For example, the whole of the absorption spectral curve of compound 1 (yellow) after conversion into the N-methyl derivative 2 (brownish-
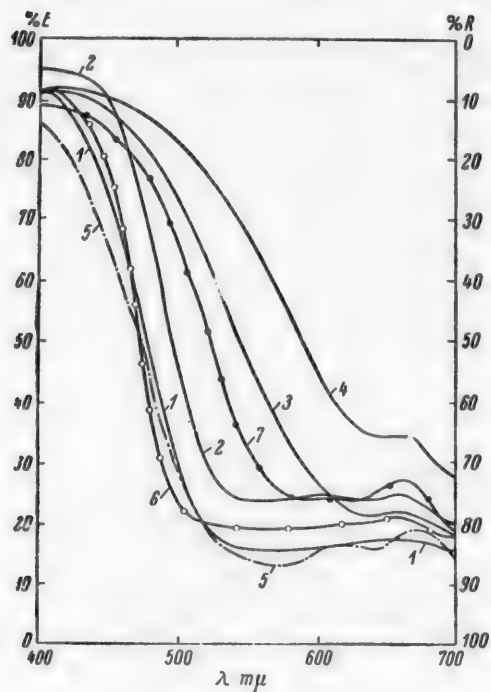
Fig. 1. Absorption spectra (of powder surface). Comparison of effect of N-methylation and of increase of number of CH_2 groups in $Q = (CH_2)_n$ with effect of introduction of p-OCH_3.
1) p-$O_2NC_6H_4CH_2CH_2NHC_6H_5$,
2) p-$O_2NC_6H_4CH_2CH_2N(CH_3)C_6H_5$,
3) p-$O_2NC_6H_4CH_2CH_2NHC_6H_4OCH_3$-p,
4) p-$O_2NC_6H_4CH_2CH_2N(CH_3)C_6H_4OCH_3$-p,
5) p-$O_2NC_6H_4CH_2NHC_6H_5$, 6) p-$O_2NC_6H_4CH_2$-$N(CH_3)C_6H_5$, 7) p-$O_2NC_6H_4CH_2NHC_6H_4OCH_3$-p.

Fig. 2. Absorption spectra (of powder surface). Effect of introduction of CH_3 into the NH group and in the para-position to the NH group.
2) $O_2NC_6H_4CH_2CH_2N(CH_3)C_6H_5$,
8) $O_2NC_6H_4CH_2CH_2NHC_6H_4CH_3$-p.

yellow) is bathochromically shifted with considerable intensification of absorption in the region of the maximum (about 400-420 mμ) and with considerable intensification of absorption throughout the whole spectrum (at 450 mμ

the percent R is displaced from 26 to 9.7) (Fig. 1, 1, 2; table). The effect of introduction of CH_3 into NH is found to be considerably greater than the effect of introduction of CH_3 in the para-position to the NH (Fig. 2, 2, 8).

* The numbers in Figs. 1 and 2 correspond to the numbering of the compounds in the table.

The curve of the N-methyl compound 2 in the 400-660 mμ region was found to be strongly displaced toward the para-methoxy compound 3. Introduction of p-OCH₃ gives a considerably stronger bathochromic shift (Fig. 1, 1, 2, 5; table) in accordance with the following scheme (Φ = p-phenylene):

$$p\text{-}O_2N\Phi CH_2CH_2NHC_6H_5 < p\text{-}O_2N\Phi CH_2CH_2NHC_6H_4CH_3\text{-}p <$$
$$< p\text{-}O_2N\Phi CH_2CH_2N(CH_3)C_6H_5 < p\text{-}O_2N\Phi CH_2CH_2NHC_6H_4OCH_3\text{-}p <$$
$$< p\text{-}O_2N\Phi CH_2CH_2N(CH_3)C_6H_4OCH_3\ p$$
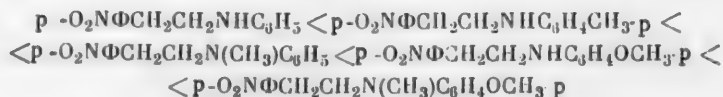
Introduction of the N-methyl group into the p-OCH₃ compound 3 gives, as was to be expected, a further considerable bathochromic effect: the orange-red 3 is transformed into the red-brown compound 4. The whole of the spectral curve of 4 is sharply displaced in the direction of deeper color (Fig. 1; 1-4). Introduction of C₂H₅ into the NH group gave a very much stronger effect than the introduction of the CH₃ group; this confirms the effect of increased size of the alkyl radical. Whereas compound 2 is only brownish-yellow in color, the N-ethyl compound 9 is already orange-yellow. The nitrogen content of compound 9, however, was found to be slightly too high (by 0.45%); its spectrum has therefore not yet been plotted. Replacement of the NH group in compounds 1 and 3 by N(CH₃) and N(C₂H₅) groups consequently gave the anticipated deepening of color.

Compound No.	Formula	Color of substance		Reflection spectra (% R for λ in m μ)				
		in crystals	in powder	400	450	500	600	700
1	$O_2N\Phi CH_2CH_2NH\Phi$ *	deep yellow	pale yellow	8.4	26.0	71.0	84.4	85.3
2	$O_2N\Phi CH_2CH_2N(CH_3)\Phi$	brownish-yellow	yellow	5.0	9.7	52.8	76.0	81.0
3	$O_2N\Phi CH_2CH_2NH\Phi OCH_3$	orange-red	orange	8.0	12.0	26.8	72.8	81.5
4	$O_2N\Phi CH_2CH_2N(CH_3)\Phi OCH_3$	red-brown	orange-red	9.0	9.5	16.5	54.0	72.5
5	$O_2N\Phi CH_2NH\Phi$	light-yellow	nearly colorless	14.0	34.0	71.6	85.0	86.4
6	$O_2N\Phi CH_2N(CH_3)\Phi$	yellow	pale-yellow	8.0	22.0	76.8	80.5	82.8
7	$O_2N\Phi CH_2NH\Phi OCH_3$	orange	light-orange	10.5	15.0	33.0	75.5	82.5
8	$O_2N\Phi CH_2CH_2NH\Phi CH_3$	yellow	pale-yellow	12.5	39.5	68.0	81.0	82.8
9	$O_2N\Phi CH_2CH_2N(C_2H_5)\Phi$	orange-yellow	dark-yellow	Spectrum not plotted				

* Φ = p-phenylene or phenyl.

2. Introduction of alkyl into the CH₂NH group of p-nitrobenzylaniline. A similar but less conspicuous bathochromic effect is observed when the NH group in p-nitrobenzylaniline is replaced by N(CH₃): compound 5 is light-yellow but 6 is yellow. The curve of 6 is shifted toward deeper color in relation to that of compound 5 (Fig. 1) (increased intensity and bathochromic shift in the 400-460 mμ region). In about the 465-510 mμ region the curves intersect and in the 520-650 mμ region the N-methyl compound possesses stronger absorption (Fig. 1; 5, 6). However, the effect of N-methylation is considerably weaker in p-nitrobenzylaniline (5) than in the p-nitrophenylethyl compound (Fig. 1; 5, 6 and 1, 2). Here again the introduction of a p-OCH₃ group into the p-nitrobenzylaniline molecule has a stronger effect; the light-yellow compound 5 is converted into orange 7 (Fig. 1; 5-7, table).

3. Influence of replacement of Q=CH₂NH by the CH₂CH₂NH group. Visual comparison of the color of compounds of the 4-nitrobenzylaniline series − 4-$O_2NC_6H_4CH_2NHC_6H_4A$-p − and of the 4-nitrophenylethyl-aniline series (I, p-A) shows that both of the series of compounds are very similar in color (compare Table 1 [8]

and Table 1 [1]). For example, in the case of A = H both compounds are yellow, but when A = p-OCH$_3$ the two compounds were previously described as red. In the present investigation we again determined the visible color, and in the table the nitrobenzyl compound 7 is already described as orange and the nitrophenylethyl compound 3 as orange-red. When A = p-OH in both cases a brownish tint is detected: red-brown in the crystals and brownish-red in the powder of the benzyl compound [8], red in the crystals and light-brown in the powder of the phenyl-ethyl compound [1]. However, color comparisons on the basis of visual impressions are extremely rough and subjective. It must be remembered that the problem is further complicated by the well-marked phenomena of chromoisomerism in compounds of both series [1, 7, 9, 10]. More accurate conclusions call for measurement of the reflection or absorption spectra of the powder surface (see Experimental) of substances isolated from the same solvent.*

It was previously observed [8] on the basis of the reflection spectra that the yellow color of N-[β-(4-nitro-phenyl)-ethyl]-aniline (1) is slightly deeper than that of N-4-nitrobenzylaniline (5), i.e., replacement of the CH$_2$NH group by the CH$_2$CH$_2$NH group leads to deepening of the color. We checked this observation by a more accurate technique of plotting of the reflection spectrum, namely the automatic recording of the reflection spectrum (or of absorption of the powder surface). Although the plots differ slightly from those previously described (Fig. 10 [8]), the earlier observation was confirmed: in the 400-460 mμ region the curve of the phenylethyl compound 1 is bathochromically shifted in relation to the curve of the benzyl compound 5, while in the 520 to 690 mμ region the curve of 1 possesses a slightly greater intensity of absorption than that of 5 (Fig. 1).

A considerably greater bathochromic shift on transition from Q = CH$_2$NH to Q = CH$_2$CH$_2$NH was manifested by the para-methoxy derivatives (table, 7 and 3, Fig. 1). The spectral absorption curve of the powder surface of the nitrophenylethyl compound 3 in the 400-600 mμ region suffered a strong bathochromic displacement; this confirms the deeper color of the CH$_2$CH$_2$NH compound 3 in comparison with 7 (Fig. 1). One may predict that the introduction into the para-methoxy compound 3 of a CH$_3$ group at the NH group will bring about a further considerable intensification of color. In the case of compounds 3-5, 7, we do actually observe the following sequence of bathochromic shifts: 5 < 7 < 3 < 4 (Fig. 1, table). The large bathochromic shift of color of compound 4 in comparison with 7 and 5 is explained by the action of three factors in the molecule of compound 4 which enhance the electron-donating ability of the chromophoric system AK and its ability to react with BK: addition to Q of a second CH$_2$ group, introduction of CH$_3$ into NH, and introduction of the p-OCH$_3$ group.

DISCUSSION OF RESULTS

Compounds of the p-nitrophenylethane series have a structure similar to that of the previously studied compounds of the 4-nitrophenylmethane series [N-(p-nitrobenzyl)-aniline] [7, 8]. The coloration of these compounds in the solid crystalline state must be due to common causes. Study of the problem of the origin of the color in 4-nitrobenzyl derivatives led to the conclusion [7] that the color cannot be associated with the formation of a continuous conjugated system of the type of B − K − A [4, 5] by isomerization into the aci-nitro form with migration of the H from the CH$_2$ group. This is confirmed by the above observation (para. 3) that replacement of Q = CH$_2$NH by the CH$_2$CH$_2$NH group leads to more deeply colored compounds, although in the latter case a continuous conjugated chain could not be formed even with rearrangement to the aci-nitro form.

On the basis of visual observations and of comparison with molecular complexes, we concluded that the color is caused by exomolecular [4] interaction of the systems AK and BK on the model of molecular complexes of nitro compounds with arylamines. Association of the molecules is possible by a dual mechanism (V, VI):

$$\underset{(V)}{\underbrace{AK - Q - BK}} \qquad \underset{}{\underbrace{BK - Q - AK}}$$
$$\underset{}{\underbrace{AK - Q - BK}} \qquad \underset{(VI)}{\underbrace{AK - Q - BK}}$$
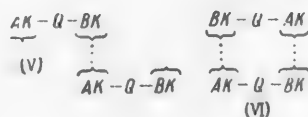
* The absorption spectra in solutions will be described in the next communication.

Certain structures of Q and favorable steric conditions can also enable direct interaction between AK and BK in the outer field due to curvature of the chain [11]. To what extent this is possible when Q = $(CH_2)_2NH$ and $(CH_2)_3NH$ must be established in further investigations.

In an attempt to account for the interaction and the color, we put forward the concept of complex mesomerism [2-4] with formation of a partial π-electron bond. This bond (the exo-bond) differs from the normal π-bond by the absence of an accompanying σ-bond. It was later suggested that this bond originates through stratified association of plane cyclic π-electron systems across the axes of π-electron clouds. This bond was named the exo-ρ-bond [4] to distinguish it from the exo-π-bond.

As far back as 1939 [3, 2, 7] we put forward the concepts of complex mesomerism in molecular complexes of the quinhydrone type and of nitroenoid systems with arylamines and phenols with formation of a partial π-bond in the absence of a σ-bond between molecules possessing different electron-accepting abilities. These ideas were thus formulated much earlier than those of Brackmann (1949, [12]) and Mulliken (1952, [13, 14]).[*] Although the fundamental cause of the color of compounds of this type has been shown to be exomolecular interaction, the question of the possibility of transmission of reciprocal effects across the connecting group still calls for discussion. As early as 1939 [7] it was suggested that the CH_2 group in the CH_2NH group plays a certain part in the micro-structure of the molecule of N-(p-nitrobenzyl)-aniline (VII). This group might be considered to exert an influence after transition into a special deformed meso state prior to ionization of the hydrogen atom: "The CH_2 group plays a part similar in some measure to the role of an auxo atom" (in modern nomenclature the group in question would be described as an electron-donating group), as illustrated by structure (VII).
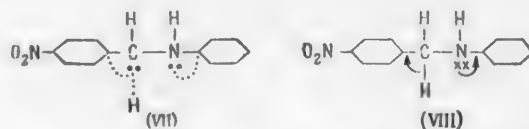
This concept harmonizes with ideas about the hyperconjugation of the CH_2 group. In modern terminology, this is known as σ, π-conjugation [15]. In terms of modern symbolism the role of the CH_2 group in endomolecular interaction can be formulated by scheme (VIII). According to the latter, the CH_2 does not participate in the transmission through the chain of the effects of the p-electrons of the NH group to the NO_2 group. Hodgson [16] later arrived at similar conclusions but he used this formula on the erroneous assumption that p-nitrobenzylaniline is not visibly colored [8]. According to scheme (VIII) the CH_2 group, due to conjugation with NO_2, should slightly lower the electron-accepting ability of the system BK, and replacement of the $p-O_2NC_6H_4CH_2$ system by, say, the $p-O_2NC_6H_4CO$ system should lead to enhancement of the electron-accepting ability and in turn to deepening of color. Hodgson [16] assumed, however, that special structural conditions would still enable direct endomolecular interaction of the NH-aryl system with the NO_2 group with participation of the CH_2 group by means of σ, π-conjugation. If this concept of Hodgson is applied to our case, the interaction of A with the NO_2 group through the medium of Q ought to be represented by Schemes (IX) and (X):

Izmail'skii and Smirnov [8] have already presented a series of considerations that demonstrate the untenability of such a concept for an explanation of the color of nitrobenzylarylamines (in the solid state). Our present work yielded the following fresh facts in opposition to Hodgson's hypothesis of the possibility of interaction of the NH-aryl system with the NO_2 system across the CH_2NH group with the help of the $\sigma\pi$-conjugation of the CH_2 group.

a) The observation that transition from the compound with $Q = CH_2NH$ (IX) to the corresponding compound with $Q = CH_2CH_2NH$ leads to a bathochromic effect. If the transmission of effects represented in schemes (IX) and (X) really occurred, then the transition from benzyl to phenylethyl compounds should undoubtedly be associated with a hypsochromic effect since the lengthening of the transmitting system ought to weaken the effect of electronic shifts. Incidentally, this bathochromic effect is fully understandable in the case of transition from CH_2NH to CH_2CH_2NH if we remember that the lengthening of the chain of an alkyl group bound to the amino group intensifies the basicity and donating ability of the NH group. Conjugation of NH with the benzene nucleus [shown in (VIII)] should be intensified (XI) because $\Delta'- > \Delta-$ and the whole of the system AK acquires enhanced electron-donating ability and a greater susceptibility to interaction with the BK system.
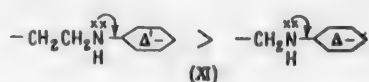
b) The observation that alkylation in the groups CH_2NH and CH_2CH_2NH causes deepening of color. The bathochromic effect in these cases is similarly explained by the increased basicity and donating ability of the N atom when the NH group in the systems AK (XII) and (XIII) is alkylated.
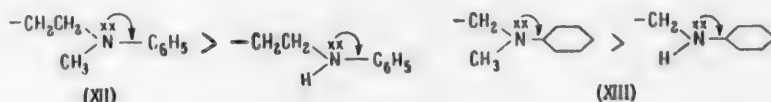
The following facts support our hypothesis that the para-two-donor system possesses a greater electron-donating ability than the corresponding meta-two-donor position [1]: The direction of shift of color and of the curve of the absorption spectrum of the powder surface on introduction of A into the para-position coincides with the direction of shift of the spectral curve when the donating ability of the NH group is strengthened by lengthening of the alkyl chain $(CH_2NH \rightarrow CH_2CH_2NH)$ or by introduction of alkyl into the NH group $[CH_2NH \rightarrow CH_2N(CH_3)$ and $CH_2CH_2NH \rightarrow CH_2CH_2N(CH_3)]$. The observation that in some cases the effect of A in the meta-position may be similar to the effect of A in the para-position clearly indicates that the electron-donating properties of system AK are intensified on introduction of a second donor not only in the event of formation of a contrapolarized system when A is inserted in the para-position, but also in the event of formation of a syn-polarized system when A is introduced in the meta-position.

EXPERIMENTAL

1. N-[β-(4 Nitrophenyl)-ethyl]-aniline. Synthesis was effected by heating the components in isoamyl alcohol [1]. Compounds 2, 3, 4, 6, 8, and 9 were similarly prepared.

2. N-[β-(4-Nitrophenyl)-ethyl]-N-methylaniline. A mixture of 7 g p-nitrophenylethyl chloride and 6 g monomethylaniline was heated 18 hours in a medium of isoamyl alcohol (30 ml) at the boil. A small quantity of concentrated hydrochloric acid was added to the reaction mixture with cooling. The precipitate of hydrochloride was suction-filtered, washed on the filter with water and treated with sodium carbonate solution to separate the amine. The latter was recrystallized from methanol. M. p. 62-63°. Yield 6.8 g (52%).

Found %: N 11.21. $C_{15}H_{16}O_2N_2$. Calculated %: N 10.93.

3. N-[β-(4-Nitrophenyl)-ethyl]-p-anisidine has been described previously [1].

4. N-[β-(4-Nitrophenyl)-ethyl]-N-methyl-p-anisidine. Similarly prepared. Was recrystallized from methanol containing carbon. M. p. 78-79°. Yield 5 g.

Found %: N 9.86. $C_{16}H_{18}O_3N_2$. Calculated %: N 9.81.

5. N-(4-Nitrobenzyl)-aniline. M. p. 68° [17].

6. N-(4 Nitrobenzyl)-N-methylaniline. The period of boiling in isoamyl alcohol was shortened to 11 hours. At the end of the reaction, the alcohol and part of the excess of N-methylaniline were removed by distillation with steam. The residue was treated with 5% hydrochloric acid and the solution was decanted. The thick, brown oil was neutralized and extracted with benzene. The benzene was distilled off. The final traces of benzene and residues of unreacted N-methylaniline were removed by freezing in vacuo (5 mm) for 10 hours at − 20°. The crystallizing mass was dissolved in methanol with heating. An oil separated from the hot solution and was isolated by decantation. On standing, the mother liquor deposited yellow plates with m. p. 46°. Yield 1.5 g.

Found %: N 11.57. $C_{14}H_{14}O_2N_2$. Calculated %: N 11.56.

7. N-(4 Nitrobenzyl)-p-anisidine. The method of preparation was similar to that for the o-anisidine derivative [18]. Yield nearly quantitative. Recrystallized from methanol containing carbon. M. p. 94-95°. Light-red color [18].

8. N-[β-(4-Nitrophenyl)-ethyl]-p-toluidine was described previously [1].

9. N-[β-(4-Nitrophenyl)-ethyl]-N-ethylaniline. Prepared on the same lines as preparation 6. Orange-yellow crystals from alcohol; m. p. 51.5°. Yield 2 g. The analysis for nitrogen gave a value 0.45% higher than that calculated for $C_{16}H_{18}O_2N_2$. For this reason the compound was not examined spectroscopically.

The reflection spectra were plotted with an automatic Hardy spectrophotometer. The fine powder was rubbed out on semi-Whatman paper. The percent light reflection in comparison with the reflection of light by a surface of compressed magnesia powder was measured (the reflection of the magnesia was taken as 100%). In order to facilitate inspection, and comparison with absorption spectra in solution, of the curves of the reflection spectra of solid substances in powder form, in diagrams with the percent of reflected light (R) plotted along the ordinates, we propose to plot the reflection spectra in the inverted form with percent of light absorbed by the powder surface (E) plotted along the ordinates (Figs. 1 and 2). Such curves of the spectra of absorption by the powder surface, with % E plotted along the ordinates on the basis of measurement of the % of R, give a clearer picture of the position of the absorption maximum and of the relative shifts of the long-wave branch in the spectral curve. It appears expedient to similarly plot the spectra of absorption by the surface of dyed fabric.

SUMMARY

1. N-methyl derivatives of N-(4-nitrobenzyl)- and N-[β-(4-nitrophenyl)-ethyl]-aniline were synthesized with the objective of checking the conclusion [1] that the deepening of the color of substances in the solid state when a second donating chromophoric component A is introduced into the para-position to a first donating chromophoric component (NH) is due to the formation of a two-donor contrapolarized system with enhanced electron-donating power.

Bathochromic shifts of the curve of the absorption spectrum of the powder surface are actually observed when the electron-donating ability is increased by change of the structure Q by introduction of a second alkyl into the NH group $[CH_2NH \rightarrow CH_2NCH_3$ and $CH_2CH_2NH \rightarrow CH_2CH_2NCH_3]$ or by lengthening of the N-alkyl group $[CH_2NH \rightarrow CH_2CH_2NH$ and $CH_2NCH_3 \rightarrow CH_2CH_2NCH_3]$. These shifts are similar to the shift of the curve on introduction of a second donor group A into the para-position to the NH , and they increase in magnitude in the following order:

$$CH_2NHC_6H_5 < CH_2CH_2NHC_6H_5 < CH_2N(CH_3)C_6H_5 < CH_2CH_2N(CH_3)C_6H_5 <$$
$$< CH_2NHC_6H_4OCH_3-p < CH_2CH_2NHC_6H_4OCH_3-p <$$
$$< CH_2CH_2N(CH_3)C_6H_4OCH_3-p$$
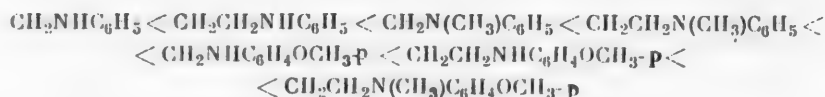
The bathochromic shifts are greater when A = p-OCH₃ than when A = H.

3. The color in the solid crystalline state (in powder) of compounds of structure (I) and of analogous derivatives of N-4-nitrobenzylaniline is caused by exomolecular interactions of the contrapolarized cochromophoric systems constituted by the electron-accepting BK ($p-O_2NC_6H_4CH_2$) and the electron-donating AK ($CH_2CH_2NHC_6H_4A-p$). These form a complex meso-system (due to the phenomenon of complex mesomerism).

4. New evidence was obtained which threw doubt on the validity of Hodgson's hypothesis of the possibility of transfer of the effect of the NH-aryl group across the CH_2 group according to schemes (IX) and (X) with the help of σ, π-conjugation.

5. A new procedure for plotting the color characteristics of substances in the solid form (powder and dyed fabric) is proposed. This involves construction of curves on the basis of measurement of the percent of reflected light (R) in the inverted form, the percent of light absorption (E) by the powder surface (or specimen of dyed fabric) being plotted along the axis of the ordinates. This form of curve facilitates inspection of the effects. It also facilitates comparison of the absorption spectra of the powder surface with the absorption spectra of solutions.

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THE ADDITION OF SILICOHYDROCARBONS TO α,β-UNSATURATED ACIDS AND THEIR ESTERS

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We recently established [1] that in presence of a catalyst — 0.1 N H_2PtCl_6 solution in isopropyl alcohol — trialkylsilanes (and arylalkylsilanes) add on to α,β-unsaturated aldehydes and ketones only in the 1,4-position with formation of silicon-containing vinyl ethers. Compounds studied in this reaction were acrolein, methyl vinyl ketone and many of their analogs with substituents in the β-position. It also appeared of interest to investigate the addition of silicohydrocarbons to α,β-unsaturated acids and their esters. Another reason for continuing the work in this direction is that the literature [2] describes the addition of methyldichlorosilane (in presence of platinized carbon in an autoclave for 16 hours at 125°) to methyl acrylate, addition being observed both in the 1,4- and 1,2-position. It was therefore a priori impossible to exclude the effect of the experimental conditions on the sequence of addition. Our own results and the experimental data submitted below showed, however, that also under our conditions methyldichlorosilane adds on simultaneously in the 1,2- and 1,4-position to methyl acrylate. It was subsequently shown that trichlorosilane adds on to this ester only in the 1,2-position, and triethylsilane adds on only in the 1,4-position (both to the ester and to the free acid). It was thereby established that the sequence of addition gradually changes with replacement of the alkyl radicals in trialkylsilanes by the more electronegative halogen atoms.

$$(C_2H_5)_3SiH + CH_2{=}CH{-}COOCH_3 \longrightarrow CH_3{-}CH{=}COSi(C_2H_5)_3$$

$$\underset{\text{(I)}}{\overset{\displaystyle |}{OCH_3}}$$

$$(C_2H_5)_3SiH + CH_2{=}CH{-}COOH \longrightarrow \left[CH_3{-}CH{=}COSi(C_2H_5)_3 \atop \overset{|}{OH} \right] \longrightarrow$$

$$\longrightarrow CH_3CH_2COOSi(C_2H_5)_3$$
$$\text{(II)}$$

$$(C_2H_5)_3SiH + CH_2{=}\underset{\overset{|}{CH_3}}{C}{-}COOCH_3 \longrightarrow (C_2H_5)_3SiCH_2\underset{\overset{|}{CH_3}}{CH}COOCH_3$$
$$\text{(III)}$$

$$Cl_3SiH + CH_2{=}CH{-}COOCH_3 \longrightarrow Cl_3SiCH_2CH_2COOCH_3$$
$$\text{(IV)}$$

$$CH_3SiHCl_2 + CH_2{=}CHCOOCH_3 \longrightarrow \begin{cases} CH_3Cl_2SiOC{=}CH{-}CH_3 \;\text{(V)} \\ \qquad\qquad \overset{|}{OCH_3} \\ CH_3Cl_2SiCH{-}COOCH_3 \;\text{(VI)} \\ \qquad\quad \overset{|}{CH_3} \\ CH_3Cl_2SiCH_2CH_2COOCH_3 \;\text{(VII)} \end{cases}$$

It was also found that triethylsilane adds on to an ester of methylmethacrylic acid in the 1,2-position, i.e., that the sequence of addition also depends on the structure of the α,β-unsaturated carbonyl compounds.

It should be pointed out that a paper recently appeared [3] in which the method of paramagnetic resonance likewise established that triethylsilane adds on in the 1,2-position to methyl methacrylate (heating for 115 hours in presence of platinized carbon) with formation of the ester of β-triethylsilylisobutyric acid.

EXPERIMENTAL

1. α-Methyl-β,β'-(methoxy)(triethylsiloxy)ethylene (I). 58 g Triethylsilane and 0.2 ml 0.1 N $H_2PtCl_6 \cdot 6H_2O$ in isopropyl alcohol were placed in a flask, and 39 g methyl acrylate was stirred in. The reaction was violent and the temperature of the reaction mass rose from 20 to 76°. The reaction was completed by heating for an hour with rise of temperature of the mixture to 150°. Fractional distillation gave 80 g of product with b. p. 70° (5 mm) (yield 82%).

$n^{20}D$ 1.4390, d^{20}_4 0.8923, MR_D 59.65; calc. 60.12.

Found %: C 59.28; H 10.37; Si 13.82. $C_{10}H_{22}O_2Si$. Calculated %: C 59.34; H 10.95; Si 13.88.

α-Methyl-β,β'-(methoxy)(methyldiethylsiloxy)(ethylene) was similarly synthesized in 64% yield (b. p. 61-62° (6 mm), $n^{20}D$ 1.4278, d^{20}_4 0.8758) from methyldiethylsilane, and α-methyl-β,β'-(methoxy)(ethyl-dibenzylsiloxy)ethylene in 31% yield (b. p. 176-178° at 3 mm, $n^{20}D$ 1.5479, d^{20}_4 1.0466) from ethyldibenzylsilane.

Hydrolysis of α-methyl-β,β'-(methoxy)(triethylsiloxy)ethylene. 25 g of (I) was placed in a flask with a reflux condenser and addition was made with shaking of 15 ml water containing 3-4 drops HCl. Heat was developed. The reaction was completed by 3 hours of heating to 70-80°. There was isolated 7 g methyl propionate with b. p. 76-77°, $n^{20}D$ 1.3779, d^{20}_4 0.9093. Literature data [4]: b. p. 79°, d^{20}_4 0.9156. The residue was triethylsilanol with b. p. 154-155°. The literature [5] gives b. p. 153-154°.

2. Triethylsilyl propionate (II) was obtained under the conditions of the preceding synthesis from 19 g acrylic acid, 0.2 ml catalyst, and 26 g triethylsilane;* yield 21 g (56%).

B. p. 68-68.5° (8 mm), $n^{20}D$ 1.4250, d^{20}_4 0.8918.

Found %: C 57.42; H 10.47; Si 14.87. $C_9H_{20}O_2Si$. Calculated %: C 57.28; H 10.70; Si 14.91.

Triethylsilyl propionate was hydrolyzed under the conditions given above. The products were propionic acid with b. p. 141-142°, $n^{20}D$ 1.3835, and triethylsilanol with b. p. 153-154°. Literature [5]: b. p. 153-154°.

3. Methyl β-triethylsilylisobutyrate (III). 9.2 g triethylsilane was added to 25 g methyl methacrylate, containing 0.2 ml catalyst, under the conditions of synthesis 1. The reaction differed from that in synthesis 1 in that the temperature of the reaction mixture did not rise spontaneously. Reaction was completed by heating to 140°. After unreacted components had been removed by distillation, the residue of 28 g was distilled at 3 mm. Yield 20 g fraction (30%) with b. p. 80-80.5°.

$n^{20}D$ 1.4430, d^{20}_4 0.8976, MR_D 63.91; calc. 63.64.

Found %: C 61.04; H 11.36; Si 12.75. $C_{11}H_{24}O_2Si$. Calculated %: C 61.11; H 11.11; Si 12.96.

Hydrolysis of this ester — by boiling 2.5 hours with sodium hydroxide and subsequent acidification with HCl — gave β-triethylsilylisobutyric acid with b. p. 126-127°, $n^{20}D$ 1.4560, d^{20}_4 0.9299.

Reaction of methyldiethylsilane with the methacrylic acid ester under the same conditions also gave the methyl ester of β-methyldiethylsilylisobutyric acid in 41% yield.

B. p. 62-63° (2 mm), $n^{20}D$ 1.4350, d^{20}_4 0.8866.

Found %: C 59.56; H 10.97; Si 14.15. $C_{10}H_{22}O_2Si$. Calculated %: C 59.35; H 10.95; Si 13.88.

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* The same compound was recently prepared by another route [6]: by the action of triethylchlorosilane on potassium propionate. The compound was reported to have b.p. 83-85° (14 mm), $n^{20}D$ 1.4202, d^{20}_4 0.8408.

4. Methyl ester of β-trichlorosilylpropionic acid (IV). Reaction was effected under the conditions of synthesis 1 between 86 g methyl acrylate and 136 g trichlorosilane (in presence of 0.3 ml catalyst) by heating for 15 hours. There was obtained 20 g (9%) of product with b. p. 90-92° (25 mm).

$n^{20}D$ 1.4483, d^{20}_4 1.3250.

Found %: C 22.10; H 3.12; Si 12.79; Cl 47.01. $C_4H_7O_2Cl_3Si$. Calculated %: C 21.62; H 3.16; Si 12.64; Cl 48.08.

Treatment of this ester with CH_3MgI gave the methyl ester of β-trimethylsilylpropionic acid with b. p. 69°, $n^{20}D$ 1.4180, d^{20}_4 0.9046. Hydrolysis of this ester led to β-trimethylsilylpropionic acid with b. p. 113° (17 mm), $n^{20}D$ 1.4290 and d^{20}_4 0.9195, for which we had previously [7] reported the following characteristics: b. p. 113° (17 mm), $n^{20}D$ 1.4292, d^{20}_4 0.9189. The acid amide was also prepared with m. p. 96-97°. Literature [8]: m. p. 95-97°.

5. α-Methyl-β,β'-(methoxy)(methyldichlorosiloxy)ethylene and its isomers. Under the conditions of synthesis 1, 115 g methyldichlorosilane was added to 86 g methyl acrylate in presence of 0.5 ml catalyst. The mixture was heated to 90°. After unreacted material had been distilled off, the residue of 148 g was fractionated in a column in vacuo. The first fraction of 20 g (10%) had the following constants:

B. p. 68-68.5° (25 mm), $n^{20}D$ 1.4300, d^{20}_4 1.1316.

Found %: C 30.37; H 5.19; Si 14.26. $C_5H_{10}O_2Cl_2Si$. Calculated %: C 29.86; H 5.0; Si 13.95.

We assigned the structure of (V) to this fraction since its ethylation (with C_2H_5MgBr) gave a product with b. p. 61-63° (6 mm), $n^{20}D$ 1.4270 and d^{20}_4 0.8769 which yielded methyl propionate when hydrolyzed.

The second fraction of 35 g (17.5%) had b. p. 81-81.5° (25 mm), $n^{20}D$ 1.4420 and d^{20}_4 1.1783. We assigned to it structure (VI) since, according to [2], the compound with this structure has the similar constants of b. p. 80-80.5° (25 mm), $n^{20}D$ 1.4382 and d^{20}_4 1.1730.

The third fraction of 8 g (4%) had b. p. 96-97° (24 mm), $n^{20}D$ 1.4445, d^{20}_4 1.1832. We assigned structure (VII) to it because similar constants are cited for the latter in [2]: b. p. 98° (25 mm), $n^{20}D$ 1.4439, d^{20}_4 1.1870.

6. α-Methyl-β,β'-(methoxy)(diethylchloroxy)ethylene and its isomer. Addition of diethylchlorosilane to methyl acrylate gave a product which could be separated into two fractions by distillation.

The first fraction had b. p. 67° (3 mm), $n^{20}D$ 1.4460, d^{20}_4 1.0261.

Found %: C 45.29; H 8.07; Cl 16.82. $C_8H_{17}O_2SiCl$. Calculated %: C 45.15; H 8.12; Cl 16.82.

We assigned to it the structure (VIII) since its ethylation gave a product with the same constants [b. p. 68-69° (8 mm), $n^{20}D$ 1.4245, d^{20}_4 0.8928] as that obtained in synthesis 1.

The second fraction, with b. p. 78-79° (3 mm), $n^{20}D$ 1.4460, d^{20}_4 1.0252, is evidently (IX).

Found %: C 46.07; H 8.06; Si 13.65; Cl 16.0. $C_8H_{17}O_2SiCl$. Calculated %: C 46.15; H 8.12; Si 13.46; Cl 16.82.

$$(C_2H_5)_2ClSiOC=CHCH_3 \qquad (C_2H_5)_2ClSiCHCOOCH_3$$
$$\underset{(VIII)}{\overset{|}{OCH_3}} \qquad\qquad \underset{(IX)}{\overset{|}{CH_3}}$$
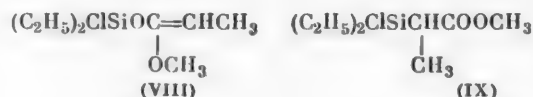
SUMMARY

1. It was shown that addition of triethylsilane to acrylic acid and its methyl ester takes place only in the 1,4-position.

2. It was established that triethylsilane adds on to methyl methacrylate only in the 1,2-position. Trichlorosilane also adds on methyl acrylate only in the 1,2-position. Consequently, the order of addition of silicohydrocarbons is determined both by their structure and by the structure of the carbonyl compounds containing a conjugated system of double bonds.

3. Addition of alkyldichlorosilanes under our conditions (in presence of H_2PtCl_6) follows the same course as when the reaction mixture is heated in presence of Pt on carbon, i.e., it occurs simultaneously in the 1,2- and 1,4-positions. Evidently, this addition mechanism is governed not by the conditions but by the character of this family of silicohydrocarbons.

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* Original Russian pagination. See C. B. Translation.

SYNTHETIC ANESTHETICS

DERIVATIVES OF 1-HYDROXYALKYL-2,5-DIMETHYLPIPERIDINE

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The 1-hydroxyalkyl-2,5-dimethylpiperidines described in one of the preceding communications[*] have been utilized for the synthesis of their esters which can be of interest both as local anesthetics of the type of methicaine and sulfocaine and for the preparation of 1-haloalkyl-2,5-dimethylpiperidines — intermediates for the synthesis of anesthetics of the phenadone group.

Benzoylation of 1-β-hydroxyethyl-2,5-dimethylpiperidine (I), 1-α-methyl-β-hydroxyethyl-2,5-dimethyl-piperidine (II) and 1-β-hydroxypropyl-2,5-dimethylpiperidine (III) gave the benzoates [(IV), (V), and (VI), respectively] of these aminoalcohols

(IV) R = R′ = H
(V) R = CH₃, R′ = H
(VI) R = H, R′ = CH₃

(I)   R = R′ = H, R″=OH
(II) R = CH₃, R′ = H, R″ = OH
(III) R = H, R′ = OH, R″ = CH₃

(VII) R = R‴ = H, R⁗ = Cl
(VIII) R = CH₃, R‴ = H, R⁗ = Cl
(IX)   R = H, R‴ = Cl, R⁗ = CH₃

(X)
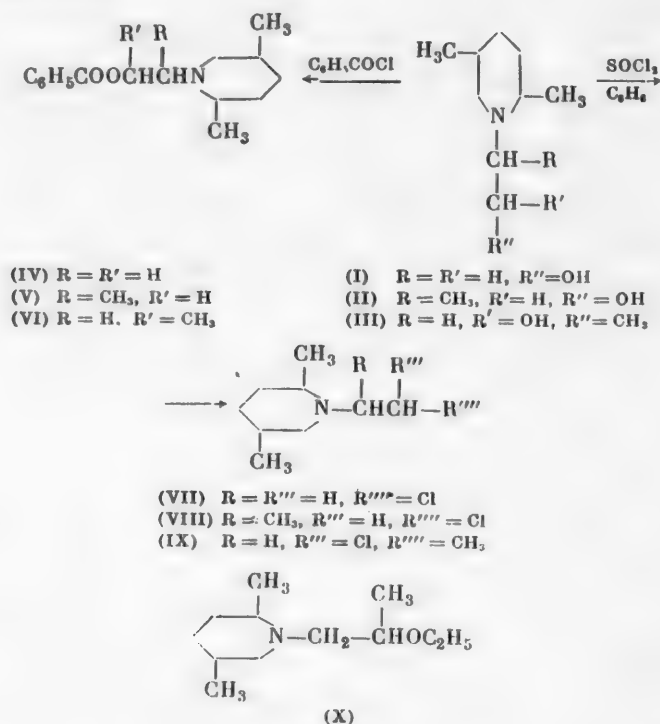
[*] J. Gen. Chem. 29, 2861 (1959). (See C. B. translation).

Replacement of the hydroxy group in aminoalcohols (I), (II), and (III) by chlorine is effected with the help of thionyl chloride. The following were obtained in yields of up to 80%: 1-β-chloroethyl-2,5-dimethylpiperidine (VII), 1-α-methyl-β-chloroethyl-2,5-dimethylpiperidine (VIII) and 1-β-chloropropyl-2,5-dimethylpiperidine (IX). Heating of the latter with 30% alcoholic potassium hydroxide gave, in addition to the expected product of dehydrochlorination, 1-β-ethoxypropyl-2,5-dimethylpiperidine (X).

EXPERIMENTAL

1-β-Benzoylhydroxyethyl-2,5-dimethylpiperidine (IV). 1.9 g 1-β-hydroxyethyl-2,5-dimethylpiperidine (I), 3.8 g benzoyl chloride and 10 ml benzene were heated 4 hours on a boiling water bath. The benzene was driven off in vacuo. The residue crystallized when ether was added. Recrystallization from acetone gave 1.2 g of the hydrochloride of (IV) with m. p. 135-137°.

Found %: N 4.48, 4.52. $C_{16}H_{24}O_2NCl$. Calculated %: N 4.70.

1-α-Methyl-β-benzoylhydroxyethyl-2,5-dimethylpiperidine (V). To a solution of 5.1 g 1-α-methyl-β-hydroxyethyl-2,5-dimethylpiperidine (II) in 25 ml anhydrous benzene (cooled with iced water) was added 3.5 ml propionyl chloride. The mixture was heated 3 hours at the boiling point of benzene. The colorless precipitate was filtered, washed with benzene, and recrystallized from alcohol. Yield 4.5 g hydrochloride of (V) with m. p. 196-199°.

Found %: Cl 11.40, 11.45. $C_{17}H_{26}O_2NCl$. Calculated %: Cl 11.40.

1-β-Benzoylhydroxypropyl-2,5-dimethylpiperidine (VI). 3.8 g 1-β-hydroxypropyl-2,5-dimethylpiperidine (III), 3.1 g benzoyl chloride and 20 ml benzene were heated 8 hours at the boiling point of benzene. The benzene was distilled off. The residue was dissolved in water and worked up with sodium carbonate in presence of ether. The products were extracted with ether, dried, and distilled in vacuo to give 1.2 g of (VI) with b. p. 138-140° (2 mm).

Found %: N 5.25, 5.31. $C_{17}H_{25}O_2N$. Calculated %: N 5.09.

1-β-Chloroethyl-2,5-dimethylpiperidine (VII). 5.6 g thionyl chloride, dissolved in 10 ml benzene, was added to a solution of 7.4 g 1-β-hydroxyethyl-2,5-dimethylpiperidine (I) in 35 ml benzene with cooling to 5° and stirring. Heating of the reaction mixture at the boiling point of benzene was continued for an hour. Benzene and excess thionyl chloride were taken off in vacuo. The residue was dissolved in water and worked up with sodium carbonate. The organic bases that separated were extracted with benzene; after drying, they were distilled in vacuo. Yield 3.6 g of (VII) with b. p. 56-57° (2 mm).

Found %: N 7.64, 7.71. $C_9H_{18}NCl$. Calculated %: N 7.97.

1-β-Bromoethyl-2,5-dimethylpiperidine was prepared from 7.5 g aminoalcohol (I) and 51 g phosphorus tribromide. The reaction was carried out as above. Heating of the ethereal extract of the basic products gave a colorless precipitate of (ethyleneimine-spiro-3,6-dimethylpiperidine)-ammonium bromide with m. p. 235° (with decomp.) (from alcohol).

Found %: N 6.51, 6.41. $C_9H_{18}NBr$. Calculated %: N 6.36.

1-α-Methyl-β-chloroethyl-2,5-dimethylpiperidine (VIII). 32 g thionyl chloride in 30 ml benzene was stirred dropwise at 0-5° into 13 g 1-α-methyl-β-hydroxyethyl-2,5-dimethylpiperidine (II) dissolved in 60 ml benzene. The experiment was run in a stream of nitrogen. The mixture was heated 2 hours at the boiling point of benzene, after which the product was worked up in the usual manner for isolation of basic reaction products. Yield 10.8 g of (VIII):

B. p. 74-76° (2 mm), $n^{20}D$ 1.4666, d^{20}_4 0.9608, MR_D 54.64; calc. 54.98.

Picrate: m. p. 151-153° (from alcohol).

Found %: N 13.02, 13.07. $C_{16}H_{23}O_7N_4Cl$. Calculated %: N 13.38.

1-β-Chloropropyl-2,5-dimethylpiperidine (IX). 18.4 g 1-β-hydroxypropyl-2,5-dimethylpiperidine (III), 17.2 g thionyl chloride and 180 ml benzene were taken for the reaction which was run as for the synthesis of (VIII). Yield 15.8 g of (IX):

B. p. 71-72° (3 mm), $n^{20}D$ 1.4640, d^{20}_4 0.9484, MR_D 55.11; calc. 55.11.

Picrate: m. p. 154-156° (from alcohol).

Found %: N 13.38, 13.56. $C_{16}H_{23}O_7N_4Cl$. Calculated %: N 13.38.

1-β-Ethoxypropyl-2,5-dimethylpiperidine (X). 2.3 g 1-β-chloropropyl-2,5-dimethylpiperidine (IX) and 20 ml 30% alcoholic potassium hydroxide were heated 5 hours on a boiling water bath. The mixture was then worked up with 10% hydrochloric acid until acid to Congo. The alcohol was distilled off in vacuo. The residue was treated with sodium carbonate and the separated organic bases were extracted with ether. Distillation in vacuo gave 1 g of (X): b. p. 85-87° (2 mm), $n^{20}D$ 1.4524.

Found %: N 7.27, 7.11. $C_{12}H_{25}ON$. Calculated %: N 7.03.

1.7 g of (X), 17 ml concentrated hydrobromic acid and 22.5 ml glacial acetic acid were heated for 5 hours at the boil. Subsequent working-up in the usual manner for separation of organic bases gave 1.3 g aminoalcohol (I) whose picrate had m. p. 98-100° and did not give a depression of melting point in admixture with an authentic specimen.

SUMMARY

1. New analogs were prepared of the known local anesthetic methicaine: 1-β-benzoylhydroxyethyl-2,5-dimethylpiperidine, 1-α-methyl-β-benzoylhydroxyethyl-2,5-dimethylpiperidine, and 1-β-benzoyl-hydroxypropyl-2,5-dimethylpiperidine.

2. The conversion of three 1-hydroxyalkyl-2,5-dimethylpiperidines into 1-haloalkyl-2,5-dimethyl-piperidines was described.

δ-LACTONES

XVII. SYNTHESIS OF ARYL- AND ALKARYL-α-PYRONES

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In the preceding communications [1-4] we described the method that we had developed for the synthesis of α-pyrones. This consisted in the detachment of two molecules of hydrogen bromide from δ-enollactone dibromides during their distillation. In this manner, we synthesized 5,6-disubstituted α-pyrones of the condensed type [1, 2], 5,6-dialkyl-α-pyrones [3] and 6-phenyl-α-pyrone [4].

In the present work this reaction was employed for the preparation of aryl- and alkylaryl-α-pyrones.

(I & IV) R = p-CH₃C₆H₄, R' = H; (II & V) R = C₆H₅, R' = CH₃; (III & VI) R = CH₃, R' = C₆H₅.

Synthesis was effected in this way of previously undescribed isomeric α-pyrones with various positions of the methyl group: 6-p-tolyl-α-pyrone (IV), 5-methyl-6-phenyl-α-pyrone (V), and 6-methyl-5-phenyl-α-pyrone (VI). The structure of these α-pyrones was confirmed by formation of double adducts (VII-IX) with maleic anhydride.

(VII) R = p-CH₃C₆H₄, R' = H; (VIII) R = C₆H₅, R' = CH₃; (IX) R = CH₃, R' = C₆H₅

The yields of α-pyrones vary considerably (from 12 to 60%) depending on the presence of substituents in the 5 and 6 positions and on their nature. This behavior fits in well with our previously proposed mechanism of the transformation of δ-enollactone dibromides into α-pyrones [5]. According to this mechanism the successive cleavage of two molecules of hydrogen bromide from dibromolactones (on distillation) goes in such a manner that an atom of bromine from the 5 position is involved in the formation of the first molecule of hydrogen bromide.

The mobility of the bromine atom in the 5 position should therefore appreciably affect the yields of α-pyrones. In fact, the dibromide (I), which does not contain a substituent in the 5 position (R' = H) and in which the bromine is attached to the secondary carbon atom, is converted into an α-pyrone in a yield of only 12%. The dibromide (II), whose bromine atom in the 5 position is at a tertiary carbon atom (R' = CH₃), gives α-pyrone (V) in 35% yield on distillation. Distillation of dibromide (III), in which the ≡C − Br group in the 5 position is part of a tertiary bromide system of the benzyl type, gives a yield of 60% of α-pyrone (VI).

Similarly to what we showed earlier [3, 4], the dehydrobromination resulting from distillation of dibromides of the aryl- and alkylaryl- δ-enollactones is accompanied by their debromination with formation of the original δ-enollactones (in yields inversely proportional to the yields of the corresponding α-pyrones).

Separation of the α-pyrones from the δ-enollactones was effected by treating the products of distillation of the dibromolactones with sodium carbonate or caustic alkali solution in the cold; the δ-enollactone completely went into the alkaline solution to form salts of the corresponding δ-ketoacids.

$$
\begin{array}{c}
R' \\
\diagup \diagdown \\
\text{CO} \quad \xrightarrow[\text{(NaOH)}]{H_2O} \quad R-CO-CH-CH_2-CH_2-COONa \\
R \diagdown \diagup O
\end{array}
$$
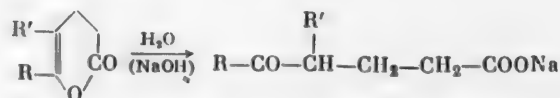
EXPERIMENTAL

Preparation of aryl- and alkylaryl-α-pyrones (IV-VI) from δ-enollactones. To a cooled solution of the δ-enollactone in absolute ether or dry carbon tetrachloride was added dropwise an equimolar quantity of bromine with cooling. After the solvent had evaporated off in vacuo, the resultant dibromides (I-III) (they fume strongly in the air due to detachment of hydrogen bromide) were distilled in vacuo over glass wool for conversion to the α-pyrones. Distillation was carried out at such a rate that it was completed in 15-20 minutes. The distillate, consisting of a mixture of α-pyrone and original δ-enollactone, crystallized on cooling (when left for 1-1.5 hours in the condenser); the crystalline mass was carefully triturated with cold 2 N sodium hydroxide solution (50 ml) for 15-30 minutes and the alkali solution was decanted from the solid. To the residue was added 50 ml 2 N sodium carbonate solution. The mass was stood for 25-30 hours at room temperature, the mixture being periodically shaken and the soda solution being changed 2-3 times. The δ-enollactone was completely removed by adding to the residue, after the soda solution had been poured off, a fresh lot of 50 ml 2 N sodium hydroxide solution and leaving at room temperature for 2-4 hours. The so-purified α-pyrone was washed with water and recrystallized 2-4 times from ligroine. Acidification of the combined alkaline and soda solutions with concentrated hydrochloric acid led to separation of the δ-ketoacid formed by alkaline hydrolysis of the δ-enollactone.

6-p-Tolyl-α-pyrone (IV). The dibromide (I), obtained from 9 g 6-p-tolyl-δ-enollactone (b. p. 183-185° at 9 mm, m. p. 64.5-65° [6]), gave 6.6 g distillate with b. p. 180-200° at 12 mm. The latter was worked up with caustic alkali and sodium carbonate as above to give 1.1 g (12%) 6-p-tolyl-α-pyrone with m. p. 102-103.5° (from ligroine).

Found %: C 77.53, 77.69; H 5.63, 5.69. $C_{12}H_{10}O_2$. Calculated %: C 77.41; H 5.41.

4 g γ-p-tolylbutyric acid was isolated from the combined alkali and soda solutions; b. p. 147-148°; a mixture with authentic γ-p-tolylbutyric acid with m. p. 148-149° [6, 7] melted without depression. This amount of acid is equivalent to 3.7 g (44%) of 6-p-tolyl-δ-enollactone.

5-Methyl-6-phenyl-α-pyrone (V). Distillation of the dibromolactone (II), obtained from 12 g 5-methyl-6-phenyl-δ-enollactone (b. p. 187° at 18 mm, m. p. 58-58.5° [6]) gave 10.7 g of distillate with b. p. 180-200° at 10 mm; this was worked up as described above and gave 4.2 g (35%) of 5-methyl-6-phenyl-α-pyrone with m. p. 93-94° (from ligroine).

Found %: C 77.36, 77.16; H 5.57, 5.47. $C_{12}H_{10}O_2$. Calculated %: C 77.41; H 5.41.

Acidification of the alkali and soda solutions yielded 2.1 g of γ-benzoylvaleric acid (m. p. 51-53°; a mixture with authentic γ-benzoylvaleric acid with m. p. 52-53° [6] melted without depression), equivalent to 1.9 g (16%) of 5-methyl-6-phenyl-δ-enollactone.

6-Methyl-5-phenyl-α-pyrone (VI). The dibromide (III), obtained from 11 g 6-methyl-5-phenyl-δ-enollactone (b. p. 163-164° at 7 mm, $n^{20}D$ 1.5582 [6]), was distilled to give 9.8 g of distillate with b.p. 170-185° at 15 mm. The distillate was worked up in the usual manner to give 6.6 g (60%) of 6-methyl-5-phenyl-α-pyrone which melted at 65.5-67° (from ligroine).

Found %: C 77.53, 77.67; H 5.63, 5.40. $C_{12}H_{10}O_2$. Calculated %: C 77.41; H 5.41.

From the alkali and soda solutions was isolated 0.43 g γ-phenyl-γ-acetylbutyric acid (m. p. 45-46.5°; a mixture with authentic γ-phenyl-γ-acetylbutyric acid with m. p. 48-49° [6] melted without depression), equivalent to 0.4 g (3.5%) of 6-methyl-5-phenyl-δ-enollactone.

Preparation of double adducts of α-pyrones with maleic anhydride (VII-IX). A solution of 0.005 mole of the α-pyrone and 0.01 mole maleic anhydride in 5 ml dry xylene was boiled 2.5-3 hours; carbon dioxide came off during the heating in the theoretical quantity (calculated on the reacted α-pyrone). Gas ceased to come off after heating for 2-2.5 hours. The adduct (yield 65-80%) came down during the boiling period. After recrystallization from xylene, the double adduct of 6-p-tolyl-α-pyrone (VII) melted at 285-286° (in a sealed capillary) (with decomp.).

Found %: C 67.91, 67.79; H 4.45, 4.46. $C_{19}H_{14}O_6$. Calculated %: C 67.45; H 4.17.

The double adduct of 5-methyl-6-phenyl-α-pyrone (VIII), after recrystallization from xylene and subsequent reprecipitation from acetone with ligroine, melted at 283-284° (in a sealed capillary).

Found %: C 67.09, 67.01; H 4.29, 4.32. $C_{19}H_{14}O_6$. Calculated %: C 67.45; H 4.17.

The double adduct of 6-methyl-5-phenyl-α-pyrone (IX), after reprecipitation from acetone with ligroine followed by recrystallization from acetonitrile, melted at 233-234° (in a sealed capillary).

Found %: C 67.34, 67.37; H 4.40, 4.30. $C_{19}H_{14}O_6$. Calculated %: C 67.45; H 4.17.

SUMMARY

1. 6-p-Tolyl-α-pyrone, 5-methyl-6-phenyl-α-pyrone and 6-methyl-5-phenyl-α-pyrone, which have not previously been described, were synthesized by bromination of aryl- and alkylaryl-δ-enollactones followed by distillation of the resulting dibromides.

2. The synthesized α-pyrones were characterized by preparation of the double adducts with maleic anhydride.

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THE SYNTHESIS OF HYDROCARBONS

LXXI. THE SYNTHESIS OF DINEOALKYLS $C_{12}H_{26} - C_{14}H_{30}$

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We recently described [1] a new general method of synthesis of 2,2,5,5-tetramethylalkanes — dineopentyl and its homologs ($C_{10} - C_{12}$ dineoalkyls) — consisting in a Grignard—Wurtz reaction between primary isoprene hydrobromide and tert-butylmagnesium chloride, hydrochlorination of the resulting 2,2,5-trimethyl-4-hexene, and a second Grignard — Wurtz reaction (in presence of mercuric chloride) between the resulting saturated tertiary chloride and alkylmagnesium bromides.

where $R = CH_3$, C_2H_5, C_3H_7, iso-C_3H_7
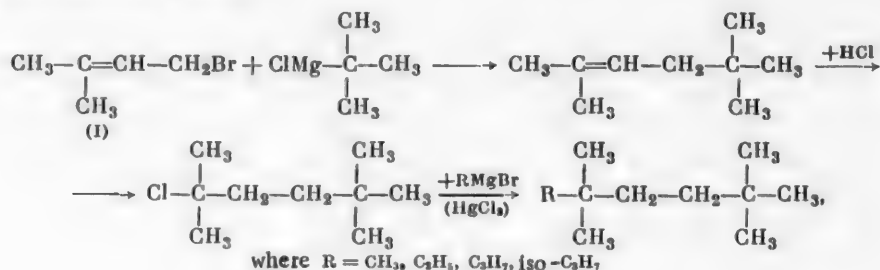
In the present work we applied this "double Grignard—Wurtz reaction" to the synthesis of $C_{12} - C_{14}$ dineoalkyls with another position of the quaternary carbon atoms in the chain — 3,3,6,6-tetramethylalkanes (dineohexyl and its homologs) and 4,4,7,7-tetramethyldecane (dineoheptyl).

Reaction of primary isoprene hydrobromide (I) with tert-amyl- and tert-hexylmagnesium chloride gave respectively (10% yield) 2,5,5-trimethyl-2-heptene and 2,5,5-trimethyl-2-octene (II):*

where $R' = C_2H_5$ & C_3H_7.
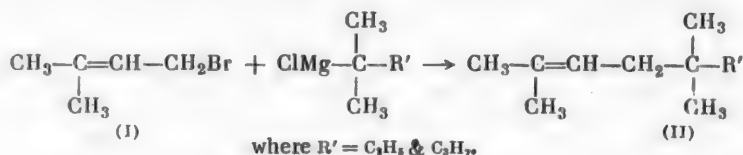
The Raman spectra of the synthesized alkenes contained the 1671 and 1668 cm^{-1} frequencies which are characteristic of tetrasubstituted olefins.

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* Catalytic hydrogenation of 2,5,5-trimethyl-2-octene gave the corresponding alkane $C_{11}H_{24}$ with one quaternary carbon atom — 2,5,5-trimethyloctane (not previously described).

2,5,5-Trimethyl-2-heptene ($R' = C_2H_5$) was also prepared by another route — by partial catalytic hydrogenation of 2,5,5-trimethyl-2,6-heptadiene (similarly formed in 12% yield side by side with 2,7-dimethyl-2,6-octadiene from isoprene hydrobromide under the action of tert-alkylmagnesium chlorides [1]); this dienic hydrocarbon contains monosubstituted ($-CH=CH_2$) and trisubstituted ($>C=CH-$) ethylenic groups which, as known from the work of S. V. Lebedev [2], must hydrogenate at different speeds. Experiments actually showed that hydrogenation in the cold of 2,5,5-trimethyl-2,6-heptadiene in presence of platinum catalyst goes with constant speed until two hydrogen atoms have added on to one mole of diene.

$$CH_3-C=CH-CH_2-\underset{\underset{CH_3}{|}}{\overset{\overset{CH_3}{|}}{C}}-CH=CH_2 \xrightarrow[(Pt)]{+H_2} CH_3-C=CH-CH_2-\underset{\underset{CH_3}{|}}{\overset{\overset{CH_3}{|}}{C}}-CH_2-CH_3$$
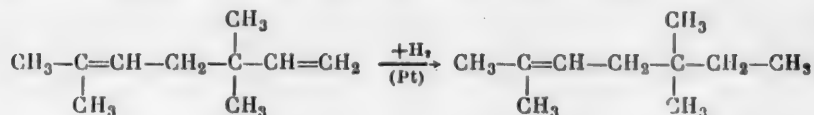
The constants and Raman spectrum of the prepared alkene (whose structure was also confirmed by ozonization) agreed with the constants and spectrum of 2,5,5-trimethyl-2-heptene synthesized by the Grignard—Wurtz reaction.

2,5,5-Trimethyl-2-heptene and 2,5,5-trimethyl-2-octene were further converted by treatment with hydrogen chloride into the saturated tertiary chlorides (III) (already containing one quaternary carbon atom; yields 93 and 75%). Treatment of the latter with organomagnesium compounds in presence of mercuric chloride gave the dineoalkyls (IV) — symmetrical and unsymmetrical alkanes with two quaternary carbon atoms separated by two CH_2 groups.

$$CH_3-C=CH-CH_2-\underset{\underset{CH_3}{|}}{\overset{\overset{CH_3}{|}}{C}}-R' \xrightarrow[(Hg\cdot Cl_2)]{+HCl} Cl-\underset{\underset{CH_3}{|}}{\overset{\overset{CH_3}{|}}{C}}-CH_2-CH_2-\underset{\underset{CH_3}{|}}{\overset{\overset{CH}{|}}{C}}-R' \xrightarrow{+RMgBr}$$

(II)   (III)

$$\longrightarrow R-\underset{\underset{CH_3}{|}}{\overset{\overset{CH_3}{|}}{C}}-CH_2-CH_2-\underset{\underset{CH}{|}}{\overset{\overset{CH_3}{|}}{C}}-R'$$

(IV)

a) $R' = C_2H_5$; $R = C_2H_5$, C_3H_7, iso-C_3H_7;
b) $R = R' = C_3H_7$
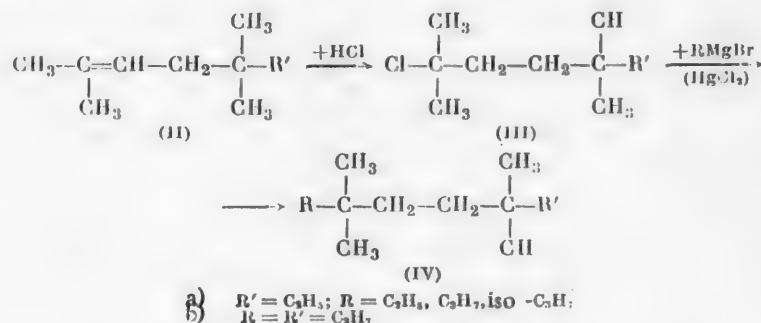
The synthesized dineoalkyls were separated by distillation in a column from the low-boiling starting alkenes (II) (yield approx. 50-55%) formed in a secondary reaction [1] by cleavage of hydrogen chloride from the tertiary chlorides (III). These alkenes contain a very small admixture of alkanes with the same carbon skeleton — products of reduction [1] of the tertiary chlorides. The alkenes were reused in the same reaction.

The yields of dineoalkyls (after purification by redistillation in a column and by chromatography on silica gel) amounted to 5-16%, reckoned on the charged tertiary chlorides (III), or to approximately 10-32%, reckoned on the tertiary chlorides (III) converted in the Grignard—Wurtz reaction.

Of the dineoalkyls synthesized in this work, only 3,3,6,6-tetramethyloctane has been described in the literature. It was synthesized (in very poor yield) by Whitmore and co-workers [3] by the action of sodium on neohexyl chloride; a complex synthesis of 3,3,6,6-tetramethyloctane was described by Birch and co-workers [4]: anodic oxidation of the sodium salt of β,β-dimethylglutaric acid monomethyl ester gave the dimethyl ester of $\beta,\beta,\beta',\beta'$-tetramethylsuberic acid; the latter was converted to the corresponding glycol which yielded the hydrocarbon via the dibromide.

EXPERIMENTAL

Synthesis of 2,5,5-trimethyl-2-heptene and 2,5,5-trimethyl-2-octene. Primary isoprene hydrobromide (2.3 moles) was reacted with organomagnesium compounds obtained (in 65-62% yields) from tertiary amyl chloride (3.6 moles; b. p. 84-85° at 744 mm, $n^{20}D$ 1.4047) and from tertiary hexyl chloride (2-chloromethyl-

pentane; 3.6 moles; b. p. 105-106° at 740 mm, $n^{20}D$ 1.4125). During the reaction the mixture was cooled to − 8 to − 5°. The procedure has been described elsewhere in more detail [5].

After the usual working-up and boiling with sodium, the reaction products were distilled in a 30-plate column; in addition to 2,5,5-trimethyl-2-alkenes, products resulting from secondary reactions of isoprene hydrobromide were collected [1]: 2,5,5-trimethyl-2,6-heptadiene (approximately 12% yield); b. p. 148.5-149° at 753 mm, $n^{20}D$ 1.4390) and 2,7-dimethyl-2,6-octadiene (yield approximately 6%; b. p. 166-167° at 750 mm, $n^{20}D$ 1.4474) [6].

The isolated 2,5,5-trimethyl-2-alkenes (II) were redistilled in a column. 2,5,5-Trimethyl-2-heptene: b. p. 154-154.5° (755 mm), $n^{20}D$ 1.4318, d^{20}_4 0.7594, MR_D 47.89. $C_{10}H_{20}$ F. Calculated 47.91.

Found %: C 85.76, 85.54; H 14.26, 14.45. $C_{10}H_{20}$. Calculated %: C 85.60; H 14.40.

Literature data [5]: b. p. 155-155.5° (744 mm), $n^{20}D$ 1.4339, d^{20}_4 0.7647.

Raman spectrum (recorded with an ISP-51 glass triprism spectrograph with a slit width of 6 cm^{-1}; frequencies were determined by linear interpolation from the lines of a standard iron spectrum; accuracy of determination ± 2 cm^{-1}. Line intensities were evaluated visually on an arbitrary scale in which the intensity of the line in the 1450 cm^{-1} region was taken to be 10 units: 229 (1, b), 267 (0.5), 307 (2), 329 (1.5), 360 (1), 387 (1.5), 406 (0.5), 444 (2.5, b), 467 (0.5), 497 (3), 536 (0.5), 619 (0), 670 (0.5 / b), 724 (10, b), 771 (2), 843 (1.5), 862 (2), 875 (2), 907 (3), 930 (2), 956 (3), 1022 (2.5), 1056 (2.5), 1104 (2), 1144 (2.5), 1198 (2.5, b), 1222 (1.5 / ϕ*), 1267 (1.5), 1296 (1), 1315 (1), 1345 (0.5), 1352 (2), 1382 (8), 1443 (10, b), 1460 (2.5/ϕ), 1671 (15).

Adduct with 2,4-dinitrophenylsulfenyl chloride [7]: m. p. 76.5° (from anhydrous alcohol).

Found %: N 7.75, 7.65. $C_{16}H_{23}O_4N_2ClS$. Calculated %: N 7.47.

2,5,5-Trimethyl-2-octene (not described in the literature): b. p. 171.5° (741 mm), $n^{20}D$ 1.4375, d^{20}_4 0.7708. MR_D 52.50. $C_{11}H_{22}$ F. Calculated 52.53.

Found %: C 85.57, 85.50; H 14.47, 14.52. $C_{11}H_{22}$. Calculated %: C 85.61; H 14.39.

Raman spectrum: 257 (1.5), 306 (3.5), 340 (1.5), 397 (1, b), 420 (0.5), 450 (2.5), 460 (3), 492 (1.5), 670 (1), 695 (2), 746 (6, b), 778 (2), 845 (1.5, db), 880 (3), 907 (2), 932 (3, b), 962 (0.5), 1015 (0), 1040 (3), 1085 (1, b), 1107 (5 / ϕ), 1144 (7), 1196 (8, b), 1417 (0.5), 1438-1460 (10, b), 1668 (15).

Hydrogenation of 2,5,5-trimethyl-2-octene was effected over alumina at 160-170°. The resulting 2,5,5-trimethyloctane (not described in the literature) was distilled over sodium in a 30-plate column.

B. p. 166.5° (738 mm), $n^{20}D$ 1.4195, d^{20}_4 0.7463, MR_D 52.94; calc. 52.99.

Reverse synthesis of 2,5,5-trimethyl-2-heptene. Partial catalytic hydrogenation of 2,5,5-trimethyl-2,6-heptadiene (41 g) was carried out in anhydrous alcohol (50 ml) at room temperature and atmospheric pressure using platinum oxide (0.03 g) as catalyst. Hydrogenation was substantially at an end after uptake of 6.9 liters hydrogen (the theoretical quantity is 7 liters). The product, distilled over sodium in a column, had the same constants (b. p. 154-154.5° at 753 mm, $n^{20}D$ 1.4318, d^{20}_4 0.7592) as the 2,5,5-trimethyl-2-heptene synthesized by the Grignard−Wurtz reaction.

Ozonization of the prepared hydrocarbon confirmed its structure as 2,5,5-trimethyl-2-heptene: from the ozonization products were isolated acetone peroxide with m. p. 130° (the literature [8] gives m. p. 131-133°) and acetone. The latter was identified as the 2,4-dinitrophenylhydrazone with m. p. 125° (a mixed sample melted without depression).

Hydrochlorination of 2,5,5-trimethyl-2-heptadiene and 2,5,5-trimethyl-2-octene. The procedure for hydrochlorination of 2,5,5-trimethyl-2-alkenes was described in the preceding communication [1]. The tertiary chlorides so obtained − 2-chloro-2,5,5-trimethylalkanes (III) − have not previously been described; on standing or distillation they partly split off hydrogen chloride. They had the following constants:

2-Chloro-2,5,5-trimethylheptane (yield 93%): b. p. 85° (25 mm), $n^{20}D$ 1.4391, d^{20}_4 0.8743. MR_D 53.18; calc. 53.25.

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* ϕ = background.

TABLE 1

Dineoalkyls of the Structure $R-\overset{\displaystyle CH_3}{\underset{\displaystyle CH_3}{C}}-CH_2-CH_2-\overset{\displaystyle CH_3}{\underset{\displaystyle CH_3}{C}}-R'$

R'	R	Name	B. p. (pressure in mm)	n_D^{20}	d_4^{20}	MR_D found	MR_D calc.	MR_D calc.**	Found (%) C	Found (%) H	Calculated (%) C	Calculated (%) H	Yield (in %)
C_2H_5	C_2H_5	3,3,6,6-Tetramethyl-octane (dineohexyl)*	185° (720)	1.4267	0.7620	57.35	57.62	57.35	84.68, 84.62	15.43, 15.42	84.61	15.39	16.5
C_2H_5	C_3H_7	3,3,6,6-Tetramethyl-nonane	152 (43)	1.4300	0.7673	62.07	62.23	62.00	84.80, 84.89	15.18, 15.11	84.69	15.31	14
C_2H_5	iso-C_3H_7	2,3,3,6,6-Pentamethyl-octane	202—203 (722), 85.5 (24)	1.4339	0.7761	61.84	62.23	61.83	84.75, 84.99	15.31, 15.10	84.69	15.31	7
C_3H_7	C_3H_7	4,4,7,7-Tetramethyl-decane	111 (25)	1.4325	0.7725	66.67	66.85	66.64	84.83, 84.84	15.27, 15.28	84.76	15.24	5

* Purity of the preparation 98.7 mole %; setting point − 73.4°. Literature data [4]: b. p. 189.7° (760 mm), n_D^{20} 1.4255, d_4^{20} 0.7617 (purity of preparation 99.0 mole %).

** Calculated from Tatevskii's scheme [9], taking into account the subtype of the chemical bond.

Found %: C 67.97, 67.81; H 11.95, 12.08. $C_{10}H_{21}Cl$. Calculated %: C 67.96; H 11.98.

2-Chloro-2,5,5-trimethyloctane (yield 75%): b. p. 110-111° (43 mm), $n^{20}D$ 1.4420, d^{20}_4 0.8730, MR_D 57.88; calc. 57.86.

Synthesis of Dineoalkyls

The reaction between alkylmagnesium bromides (1.65 moles alkyl bromide, 36 g magnesium and 450 ml absolute ether) and 2-chloro-2,5,5-trimethylalkanes (tertiary chlorides (III), 0.75 mole) was performed in presence of mercuric chloride (4 g) by the procedure described earlier [1]. The first distillation of reaction products (using a dephlegmator) gave low-boiling fractions (approximately 50%) of the original alkenes — 2,5,5-trimethyl-2-heptene and 2,5,5-trimethyl-2-octene (which were reused for preparation of tertiary chlorides)— and fractions of dineoalkyls which were then boiled with sodium for complete removal of halogen and distilled in a column. The isolated dineoalkyls (not described in the literature apart from dineohexyl) were redistilled in a column and purified by chromatography on silica gel. The constants and yields of the hydrocarbons are presented in Table 1.

The Raman spectra of the dineoalkyls, recorded under the above conditions, are presented in Table 2.

TABLE 2
Raman Spectra of Synthesized Dineoalkyls (C_{12} – C_{14}) *

3,3,6,6-Tetra-methyloctane	3,3,6,6-Tetra-methylnonane	2,3,3,6,6-Penta-methyloctane	4,4,7,7-Tetra-methyldecane
175 (0.5), 224 (1)	237 (2), 244 (0)	225 (1.5, b)	233 (2.5, b)
276 (1), 314 (0.5)	274 (0.5), 298 (0)	276 (0.5), 299 (0.5)	295 (4, b)
333 (1), 372 (0.5)	340 (2.5, b), 365 (0)	333 (1, b), 387 (1.5, b)	333 (4, b), 373 (0.5)
406 (1.5), 446 (1)	406 (2), 460 (1)	421 (0.5), 460 (0.5, b)	413 (1), 446 (0.5, b)
480 (0.5)	—	494 (1.5, db/ bk)	
502 (2), 544 (1)	500 (2.5, b), 547 (1)	518 (1), 556 (1)	501 (2.5, b), 547 (1)
567 (0.5), 678 (0.5)	—	569 (0), 634 (0.5)	
—	—	671 (0), 691 (2)	700 (0.5)
738 (8.5, b)	722 (4), 758 (2, b)	734 (7, b), 769 (1, b)	746 (2.5, b), 790 (3, b)
—	822 (0), 833 (0.5 / bk)	833 (1)	825 (0.5)
864 (2.5), 884 (2)	868 (1), 882 (4)	862 (0.5, b), 884 (1)	862 (0.5), 882 (4)
915 (2.5), 930 (3)	912 (2.5), 934 (2.5)	915 (4), 930 (2)	915 (2.5), 935 (2.5)
956 (0.5, b), 989 (0.5)	956 (0.5)	956 (1), 996 (0)	
1010 (3.5), 1050 (1)	1015 (1), 1040 (4)	1015 (1.5), 1040 (1)	1004 (1), 1040 (5)
1080 (3)	1056 (0), 1085 (1)	1085 (0.5)	
1137 (1, b)	1102 (1.5 / bk)	1098 (1), 1136 (1.5, b)	1102 (3 / bk)
	1144 (3, b)		1140 (3, b)
1170 (1), 1196 (4, b)	1170 (0), 1196 (6 / bk)	1170 (0.5), 1196 (4, b)	1170 (1 / bk)
			1196 (10, b)
1230 (1.5)	1227 (1)	1234 (2)	1227 (0.5), 1267 (0.5)
1318 (0)	1296 (1), 1323 (2, b)	1296 (1.5), 1323 (1.5, b)	1296 (1), 1320 (2.5, b)
1344 (2), 1359 (1)	1342 (0.5), 1355 (1.5)	1355 (1)	—
1386 (2)	1380 (1)	1388 (1.5), 1417 (0.5)	1382 (1)
1443 (10), 1464 (3)	1440 (10), 1464 (3)	1443 (10), 1464 (3)	1440 (10), 1464 (4)

* b = broad, bk = background, db = doublet.

The spectrum of dineohexyl (3,3,6,6-tetramethyloctane) was plotted with the help of a photometer; intensities were evaluated objectively against those of cyclohexane, the intensity of the 802 line of cyclohexane being taken as 500 units/mole and cm^{-1}: 175 (20), 224 (48), 276 (40), 314 (20), 333 (40), 372 (20), 406 (35), 446 (30), 480 (20), 502 (88), 544 (43), 567 (20), 678 (20), 738 (360, b), 864 (140), 884 (140), 915 (205), 930 (205), 956 (20, b), 989 (175), 1010 (175), 1050 (175), 1080 (140), 1137 (26, b), 1170 (30), 1196 (680, b), 1230 (680), 1318 (280), 1344 (280), 1359 (280), 1386 (280), 1443 (720), 1464 (720).

The presence of quaternary carbon atoms in the hydrocarbon was confirmed by the strong frequencies in the 915-930 and 1196-1230 cm^{-1} region.

SUMMARY

Synthesis of the following $C_{12} - C_{14}$ dineoalkyls from isoprene was effected by the previously developed general method of synthesis ("double Grignard — Wurtz reaction"): 3,3,6,6-tetramethyloctane (dineohexyl) and the previously undescribed 3,3,6,6-tetramethylnonane, 2,3,3,6,6-pentamethyloctane and 4,4,7,7-tetramethyldecane.

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INVESTIGATIONS IN THE FURAN SERIES

I. THE SYNTHESIS OF N-(β-HYDROXYALKYL)-FURFURYLAMINES

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Very little work has been published on the synthesis of N-(β-hydroxyalkyl)-furfurylamines. Braun [1] has described the preparation of N-(β-hydroxyalkyl)-furfurylamines by the action of ethylene oxide on a chloroform solution of methyl and ethylfurfurylamine with heating in sealed tubes. Campbell and co-workers [2] later obtained N-(β-hydroxyethyl)-N-benzylfurfurylamine in 60% yield by heating ethylene oxide with benzylfurfuryl-amine in an autoclave at 100°. Holdren and Hixon [3] showed that the action of ethanolamine hydrochloride and formaldehyde on 2-methylfuran leads to aminomethylation of the furan ring with formation of 5-(β-hydroxy-ethylamino)-methyl-2-methylfuran; this reaction does not take place with furan. A. A. Ponomarev and co-workers [4] prepared N-(β-hydroxyethyl)-2-furfurylamine by interaction of furfural with ethanolamine followed by catalytic hydrogenation in an autoclave of the resulting Schiff base. In 1954, Drefahl and König [5] reported the synthesis of di-(N-β-hydroxyethyl)-furfurylamine (from furfural, diethanolamine and formic acid); they describe the product as a red oil which forms a picrate (with m. p. 242°) as well as a hydrochloride (melting point not given).

In the present work we studied the preparation of mono-N-(β-hydroxyalkyl)-furfurylamines from 2-furfuryl-amine and the simplest α-oxides (ethylene oxide and propylene oxide) by the method previously developed by two of us [6, 7]. This consisted in passage of a stream of ethylene oxide into the amine taken in slight excess. This procedure gave the corresponding N-(β-hydroxyalkyl)-furfurylamines in a yield of 86%. By increasing the molar proportions of α-oxides in the reaction with furfurylamine, we succeeded in obtaining di-N-(β-hydroxy-alkyl)-furfurylamine in yields of 83.5-92.5%. The di-N-(β-hydroxyethyl)-furfurylamine that we prepared had properties markedly different from those of the preparation described by the German authors [5]: it was a color-less oil whose refractive index was higher; the picrate melted at 127-128°. The infrared spectrum of our compound confirms its structure: the valence vibrations of the N—H bond are absent and there is a broad band characteristic of the O—H group. A crystalline hydrochloride was not obtained when hydrogen chloride was passed into the chloroform solution. Treatment with thionyl chloride gave the hydrochloride of di-N-(β-chloroethyl)-furfuryl-amine; by treating the latter with sodium sulfide we obtained N-(2-furfuryl)-thiomorpholine.

$$(R = H, CH_3)$$

Furan—$CH_2N(CH_2CH_2OH)_2$ $\xrightarrow{SOCl_2}$ Furan—$CH_2N(CH_2CH_2Cl)_2$ · HCl $\xrightarrow{Na_2S}$ Furan—CH_2—N(thiomorpholine)
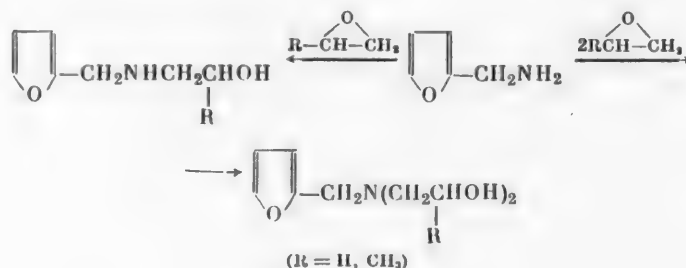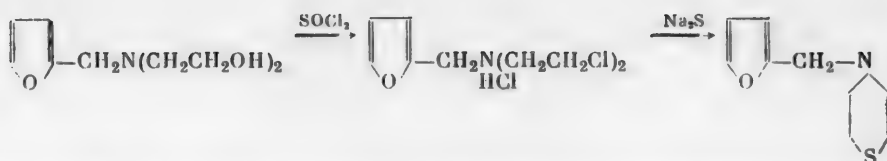
The foregoing data in support of the structure of di-N-(β-hydroxyethyl)-furfurylamine show that Drefahl and König [5] mistakenly assigned its structure to another compound.

Di-(2-furfurylamine) reacts with α-oxides to form N-(β-hydroxyalkyl)-difurfurylamines in good yield.

Furan—CH_2—NH—CH_2—Furan $\xrightarrow{R-CH-CH_2 (O)}$ Furan—CH_2NCH_2—Furan with CH_2, $RCHOH$ (R = H, CH_3)
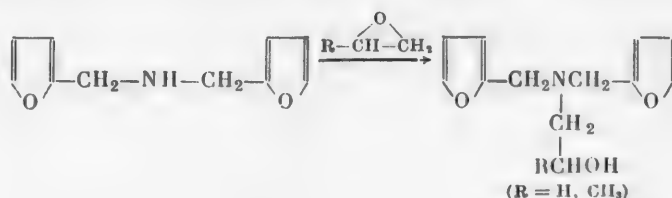
EXPERIMENTAL

2-Furfurylamine and di-(2-furfuryl)-amine were prepared by reduction of 2-furaldehyde oxime with zinc in acetic acid. From 45 g (0.2 mole) of the oxime was obtained: a) 20 g 2-furfurylamine:

B. p. 40-41° (10 mm), $n^{20}D$ 1.4895, d^{20}_4 1.0533, MR_D 26.63. $C_5H_7ON_{F_2}$. Calculated 27.21.

Literature data [8]: b. p. 83° (85 mm), d^{20}_4 1.0505, $n^{20}D$ 1.4906.

b) 9 g di-(2-furfuryl)-amine:

B. p. 115-116° (10 mm), $n^{20}D$ 1.5168, d^{20}_4 1.1045, MR_D 48.52. $C_{10}H_{11}O_2N_{F_4}$. Calculated 49.00.

Literature data [9]: b. p. 102-103° (1 mm).

N-(β-Hydroxyethyl)-furfurylamine. 70 g (0.72 mole) furfurylamine was placed in a broad test tube connected to a reflux condenser and a gas-discharge tube. 1.5-2 ml alcohol and a few drops of water were added and a stream of ethylene oxide (10.5 g, 0.24 mole) was passed through at a rate of 5-6 g/hr. During this operation the mixture spontaneously reached a temperature of 50-60°. Fractional vacuum distillation gave 54 g unchanged furfurylamine and 20 g N-(β-hydroxyethyl)-furfurylamine (86.5% calculated on the amine consumed) as a color-less liquid.

B. p. 102-102.5° (0.5 mm), $n^{20}D$ 1.5038, d^{20}_4 1.1187, MR_D 37.35. $C_7H_{11}O_2N_{F_2}$. Calculated 38.16.

Found %: N 10.06, 9.99. $C_7H_{11}O_2N$. Calculated %: N 9.92.

Literature data [4]: b. p. 116-118° (3 mm), $n^{20}D$ 1.5037, d^{20}_4 1.1184.

N-(β-Hydroxyethyl)-furfurylamine picrate was prepared by mixing benzene solutions of the base and picric acid: m. p. 131-131.5° (from alcohol).

Found %: N 15.05, 14.87. $C_{13}H_{14}O_9N_4$. Calculated %: N 15.13.

There was also isolated 0.5 g di-N-(β-hydroxyethyl)-furfurylamine. Starting from ethylene oxide furfuryl-amine molar ratios of 1:2 and 1:4, the yields of N-(β-hydroxyethyl)-furfurylamine were respectively 72.5 and 91% calculated on the furfurylamine consumed (or 34.7 and 61% on the ethylene oxide taken).

N-(β-Hydroxypropyl)-furfurylamine. Reaction components were 54 g (0.555 mole) furfurylamine and 10.7 g (0.185 mole) propylene oxide (b. p. 34-35° (760 mm), $n^{20}D$ 1.3672). 12 g of the amine reacted. There was obtained 16.5 g of product (86% calculated on the amine reacted).

B. p. 142-143° (15 mm), $n^{20}D$ 1.4930, d^{20}_4 1.0681, MR_D 42.22. $C_8H_{13}O_2NF_2$. Calculated 42.78.

Found %: N 9.09, 9.04. $C_8H_{13}O_2N$. Calculated %: N 9.03.

N-(β-Hydroxypropyl)-furfurylamine picrate: m. p. 92-93° (from alcohol).

Found %: N 14.55, 14.74. $C_{14}H_{16}O_9N_4$. Calculated %: N 14.58.

From the reaction product was also isolated 2.5 g di-N-(β-hydroxypropyl)-furfurylamine.

N-(β-Hydroxyethyl)-difurfurylamine. Reaction components were 8.85 g (0.05 mole) difurfurylamine and 3.3 g (0.075 mole) ethylene oxide. 6.75 g of the amine entered into reaction to give 7.2 g derivative (83% reckoned on the amine reacted):

B. p. 140-143° (0.5 mm), $n^{20}D$ 1.5180, d^{20}_4 1.1441, MR_D 58.60. $C_{12}H_{15}O_3NF_4$. Calculated 60.09.

Found %: N 6.28, 6.11. $C_{12}H_{15}O_3N$. Calculated %: N 6.33.

N-(β-Hydroxyethyl)difurfurylamine picrolonate: m. p. 172-173° (from alcohol).

Found %: N 14.04. $C_{22}H_{23}O_8N_5$. Calculated %: N 14.43.

N-(β-Hydroxypropyl)-difurfurylamine. Components: 7.1 g (0.04 mole) difurfurylamine and 3.5 g (0.06 mole) propylene oxide. 5 g reacted to give 5.7 g (80% reckoned on the amine reacted).

B. p. 160-163° (12 mm), $n^{20}D$ 1.5050, d^{20}_4 1.1018, MR_D 63.34. $C_{13}H_{17}O_3NF_4$. Calculated 64.72.

Found %: N 6.10, 6.31. $C_{13}H_{17}O_3N$. Calculated %: N 5.95.

Di-N-(β-hydroxyethyl)-furfurylamine. Components: 9.7 g (0.1 mole) furfurylamine and 11 g (0.25 mole) ethylene oxide. 9.2 g amine entered into reaction to give 14 g (83.5 g reckoned on the amine reacted) of a perfectly colorless liquid.

B. p. 147-148° (0.5 mm), $n^{20}D$ 1.5078, d^{20}_4 1.1423, MR_D 48.32. $C_9H_{15}O_3NF_2$. Calculated 49.26.

Found %: N 7.76, 7.79. $C_9H_{15}O_3N$. Calculated %: N 7.56.

Di-N-(β-hydroxyethyl)-furfurylamine picrate: m. p. 127-128° (from alcohol).

Found %: N 13.41, 13.24. $C_{15}H_{18}O_{10}N_4$. Calculated %: N 13.52.

Literature data [5]: a viscous, dark-red oil with b. p. 174-176° (1.2 mm), $n^{20}D$ 1.496; picrate with m. p. 242°.

Di-N-(β-hydroxypropyl)-furfurylamine. 6.8 g (0.07 mole) furfurylamine and 10 g (0.175 mole) propylene oxide were taken. 5.6 g of amine reacted. Yield 11.4 g (92.5%).

B. p. 158° (12 mm), 135-136° (1.5 mm), $n^{20}D$ 1.4905, d^{20}_4 1.0982, MR_D 56.20. $C_{11}H_{19}O_3NF_2$. Calculated 58.49.

Found %: C 61.62, 61.49; H 9.07, 9.02; N 6.81. $C_{11}H_{19}O_3N$. Calc. ated %: C 61.94; H 8.98; N 6.57.

There was also isolated 0.7 g N-(β-hydroxypropyl)furfurylamine.

N-(2-Furfuryl)-thiomorpholine. Dropwise addition (over 30 minutes) was made of 26.2 g (0.22 mole) of thionyl chloride in 20 ml chloroform to a solution of 18.5 g (0.1 mole) di-N-(β-hydroxyethyl)-furfurylamine in 50 ml chloroform saturated with hydrogen chloride. The mixture was thereupon heated 2 hours on a water bath at 50° and the chloroform was distilled off. The residue was dissolved in anhydrous alcohol and ether was added to bring out di-N-(β-chloroethyl)-furfurylamine in the form of a heavy, viscous oil which only crystallized partly after long standing.

10 g (about 0.04 mole) of the unpurified hydrochloride and 38 g (0.12 mole) crystalline sodium sulfide in 60 ml alcohol were heated 5 hours on a boiling water bath. After separation from sediment and removal of the alcohol in vacuo, the residue was extracted 3 times with ligroine. The extracts were dried with sodium hydroxide; distillation in vacuo gave 3.8 g N-(2-furfuryl)-thiomorpholine:

B. p. 101-102° (1.5 mm), $n^{20}D$ 1.5434, d^{20}_4 1.1422, MR_D 50.57. $C_9H_{13}ONS_{F_2}$. Calculated 51.68.

Found %: C 58.68, 58.49; H 7.33, 7.30; N 7.39, 7.33. $C_9H_{13}ONS$. Calculated %: C 59.01; H 7.15; N 7.65.

N-(2-Furfuryl)-thiomorpholine picrate: m. p. 165-166° (from methanol).

Found %: N 13.01, 12.91. $C_{15}H_{16}O_8N_4S$. Calculated %: N 13.59.

SUMMARY

2-Furfuryl- and di-(2-furfuryl)-amine easily react with ethylene oxide and propylene oxide to form, respectively, mono- and di-N-(β-hydroxyalkyl)-furfurylamines and N-(β-hydroxyalkyl)-difurfurylamines in yields of 80-92.7 %.

The preparation of N-(2-furfuryl)thiomorpholine from di-N-(β-hydroxyethyl)-furfurylamine confirms the structure of the latter. Its properties differ from those described in the literature.

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INVESTIGATIONS IN THE FURAN SERIES

II. REACTIONS OF FURAN DERIVATIVES WITH ETHYL AZODIFORMATE

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Compounds of the pyridazine series, an important class of physiologically active substances, find application also as plant-growth stimulators [1] and as amebicides [2].

One of the general methods of synthesis of pyridazine systems is the reaction of dienic hydrocarbons with esters of azodiformic acid. Diels, Blom and Koll [3] were the first to describe the reaction of cyclopentadiene with diethyl azodiformate; they showed that the adduct is 3,6-endomethylene-1,2-dicarboethoxy-Δ^4-tetrahydropyridazine; its hydrogenation followed by hydrolysis gave 3,6-endomethylenehexahydropyridazine. This reaction was later extended to other dienic hydrocarbons [4-10], also to styrene [4, 11], indene [4] and anthracene [5, 9].

Furan has little dienic reactivity and therefore forms adducts — derivatives of 3,6-endoxocyclohexene — only with extremely active dienophiles such as maleic anhydride [12, 13], maleic acid [14], fumaronitrile [15], acetylene dicarboxylic acid [13, 16], trifluorocrotonic acid [17], and benzoylpropionic acid [18]. Furan does not enter into the diene synthesis with such dienophiles as dimethylmaleic anhydride [19, 20], dibenzoylethylene, citraconic anhydride, chloromaleic anhydride [21] and benzoylvinylphenylsulfone [22]. Nor do furan and sylvan enter into the diene synthesis with dienophiles possessing one electronegative group (acrolein or methyl vinyl ketone), although they undergo substitutive addition with the latter [23, 24].

Any dienic synthesis with furan is of course of interest since catalytic hydrogenation of the adducts easily leads to derivatives of 3,6-endoxocyclohexane which possess physiological activity and are employed as herbicides, insecticides, defoliants [25-29], and hypotensive agents [30]. This class of compounds also includes some natural substances such as cantharidin.

Concerning the reactions of furans with diethyl azodiformate, Alder and co-workers [9] reported that the latter reacts with furfuryl diacetate to form an unstable crystalline adduct of normal structure. The authors claimed confirmation of the structure by hydrogenation followed by oxidation to give diethyl hydrazodiformate and succinic acid.

In the present work we studied the reactions of diethyl azodiformate with furan, 2-methylfuran (sylvan), and furfuryl alcohol.

Completion of this work was followed by the appearance of a paper by Baranger and Levisalles [8] in which an attempt to bring furan, 2-methylfuran and 2,5-dimethylfuran into reaction with diethyl azodiformate was described. These authors failed to isolate the adducts and to confirm their structure; equally unsuccessful was their attempt to subject the reaction products to alkaline and acid hydrolysis.

We found that reaction of furan and 2-methylfuran with diethyl azodiformate goes in the manner of a diene synthesis and leads to quantitative yields of 3,6-endoxo-1,2-dicarboethoxy-Δ^4-tetrahydropyridazine (I) and 3-methyl-3,6-endoxo-1,2-dicarboethoxy-Δ^4-tetrahydropyridazine (II), respectively. These reactions must be performed in a large volume of ether because of the great violence of the reaction in the absence of a solvent

which results in resinification of the products. Adducts (I) and (II) are noncrystalline, vitreous solids, easily grindable to a powder and softening when heated to 50-60°. We may note that a fairly large number of noncrystalline adducts are described in [3, 4, 11]. Unlike the adduct of diethyl azodiformate with furfuryl diacetate [9], our adducts have fairly good thermal stability (up to 100-120°) but attempts to distill them in vacuo only resulted in resinification.

Adducts (I) and (II) readily combine with bromine to form hard, vitreous dibromides (III); the reaction with phenylazide [31, 32] goes very slowly and leads only in the case of adduct (I) to the corresponding crystalline thiazoline derivative (IV). Attempts to prepare crystalline derivatives by the action of mercury acetate [5] and dinitrophenylsulfenyl chloride [33] were unsuccessful.

Adducts (I) and (II) take up hydrogen in presence of platinum, but the hydrogenated products (V) are in the form of a dark, vitreous mass. Distillation in vacuo is accompanied by pyrolysis with formation of the diethyl ester of hydrazodiformic acid (VI).
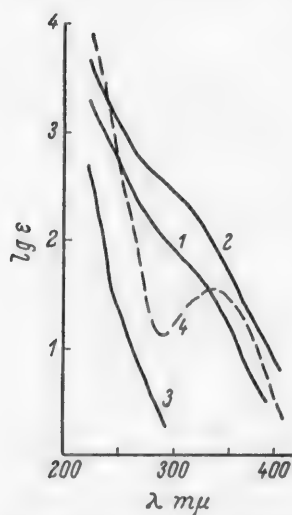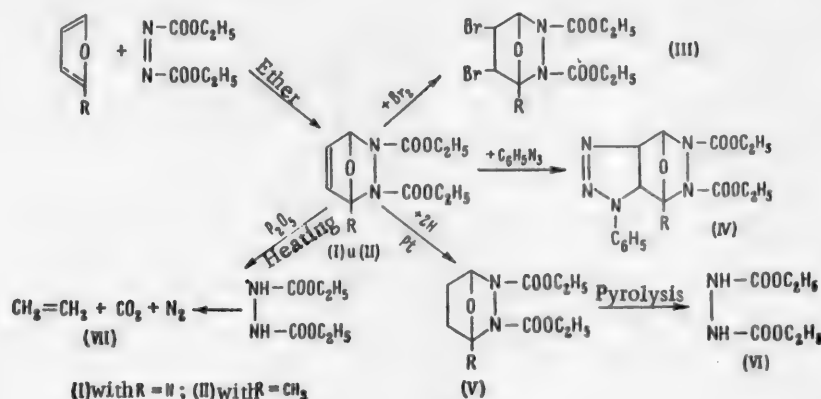
We know from [10] that attempts to aromatize 1,2-dicarboethoxy-Δ^4-tetrahydropyridazine by heating with phosphorus pentoxide result in loss of carbon dioxide and in resinification; rapid heating in some experiments led to a small yield of Δ^4-tetrahydropyridazine-1,2-dicarboxylic acid.

We found that heating of adducts (I) and (II) with phosphorus pentoxide likewise results in resinification also in detachment of carbon dioxide and ethylene and formation of a small quantity of the diethyl ester of hydrazodiformic acid. When diethyl hydrazodiformate was heated with phosphorus pentoxide, we observed that it decomposed and resinified with loss of carbon dioxide and ethylene.

Decomposition of adducts (I) and (II) under the action of phosphorus pentoxide is thus accompanied by formation of diethyl hydrazodiformate which undergoes further breakdown with formation of ethylene, carbon dioxide and nitrogen (VII). Alkaline hydrolysis of adducts (I) and (II), as well as of the products of their hydrogenation [3, 5, 7], gives an aqueous alkaline solution of the corresponding pyridazine, but attempts to isolate the latter were unsuccessful. Nor could it be isolated as the picrate [5], the copper chloride complex [3] or the benzoyl derivative.

The chemical properties of adducts (I) and (II), and especially the formation of a crystalline product of addition of phenylazide to adduct (I), indicate that the reaction of furan and sylvan with azodiformic ester is a normal diene synthesis. The ultraviolet absorption spectra of adducts (I) and (II), and of the 3,6-endoxo-Δ^4-dicyclohexene-1,2-dicarboxylic acid [14] taken for comparison (see diagram), do not exhibit selective absorption in the 220-400 mμ region. This is further confirmation of the structure of these adducts.

Ultraviolet absorption spectra: 1) 3,6-endoxo-1,2-dicarbo-ethoxy-Δ^4-tetrahydropyridazine; 2) 3-methyl-3,6-endoxo-1,2-dicarboethoxy-Δ^4-tetrahydropyridazine; 3) 3,6-endoxo-Δ^4-cyclohexene-1,2-dicarboxylic acid; 4) diethyl ester of N-(2-furoxy)-hydrazodiformic acid.

In connection with the reaction of furfuryl alcohol with diethyl azodiformate, we know that the latter reacts with alcohols [34], so that we can expect a reaction on the lines of the diene synthesis, but at greater speed, with formation of a product of addition of the alcoholic group.

Using a 1 : 1 molar ratio of reactants, we obtained a crystalline addition product which resinified under the action of bromine, did not give characteristic reactions for the alcohol group and added on two molecules of hydrogen with formation of a viscous, dark oil. The latter pyrolyzed during distillation and formed the diethyl ester of hydrazodiformic acid; the latter is also formed during oxidation of the product of hydrogenation by Alder's method [9]. The ultraviolet absorption spectrum of this addition product differs from the spectra of adducts (I) and (II) in having a maximum with λ_{max} 340, log ϵ_{max} 1.56; the infrared absorption spectrum indicates the presence of a furan ring and an NH group in this compound. In the light of all these facts we can assign to the product of interaction of furfuryl alcohol with diethyl azodiformate the structure of the diethyl ester of N-(2-furoxy)-hydrazodiformic acid.
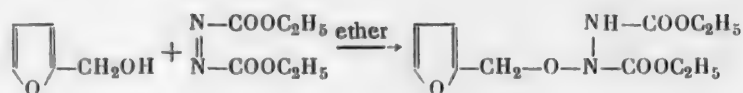
EXPERIMENTAL

Adduct (I). 3,6-Endoxo-1,2-dicarboethoxy-Δ^4-tetrahydropyridazine. 13.6 g (0.2 mole) furan in 30 ml absolute ether was mixed in a flask with a reflux condenser with 30 g (0.17 mole) of diethyl azodiformate in 60 ml absolute ether. The flask was cooled at intervals with cold water since the reaction is exothermic. After 24 hours (when the color of the azodiformate had disappeared) the ether was distilled off (final traces were removed by heating in vacuo at 50°). There was obtained 39 g very viscous oil which solidified to a transparent glassy mass which could be easily pulverized. The adduct was soluble in alcohol, ether, benzene, and chloroform; it was insoluble in water, cyclohexane and ligroine.

Found %: C 49.38, 49.21; H 5.93, 5.97; N 11.49, 11.56. M 230, 236 (According to Rast). $C_{10}H_{14}O_5N_2$. Calculated %: C 49.56; H 5.82; N 11.57. M 242.

3,6-Endoxo-1,2-dicarboethoxy-4,5-dibromohexahydropyridazine. A solution of bromine in carbon tetrachloride was added dropwise to a solution of 2 g adduct (I) in 10 ml carbon tetrachloride at − 15° until the decolorization ceased. The oil that separated out was triturated with sodium bisulfite solution and dissolved in ether. The ether extract was dried with sodium sulfate and the solvent was evaporated. There was obtained 2.5 g of dibromo derivative in the form of a transparent glassy mass.

Found %: Br 39.64, 39.61. $C_{10}H_{14}O_5N_2Br_2$. Calculated %: Br 39.76.

3,6-Endoxo-1,2-dicarboethoxy-4,5-(1-phenyltriazolino)-hexahydropyridazine. 0.5 g adduct (I) was dissolved in 1 ml phenylazide by shaking. After a month the reaction mixture solidified to a crystalline mass. The crystals were washed with a little acetone and recrystallized from aqueous alcohol; m. p. 124-124.5°.

Found %: C 53.21, 53.31; H 5.45, 5.49; N 19.07, 19.25. $C_{16}H_{19}O_5N_5$. Calculated %: C 53.17; H 5.30; N 19.36.

Decomposition of adduct (I) with phosphorus pentoxide. 3 g adduct (I) was heated in a Wurtz flask with 3.5 g phosphorus pentoxide until a vigorous reaction commenced. A small quantity of crystalline substance collected in the receiver; m. p. 131-131.5° (from benzene); a mixture with authentic diethyl ester of hydrazo diformic acid did not give a depression of melting point.

Found %: C 41.09, 40.93; H 6.84, 6.98. $C_6H_{12}O_4N_2$. Calculated %: C 40.90; H 6.89.

The gases evolved during the reaction were passed through a solution of bromine in carbon tetrachloride and through barite water. Carbon dioxide was detected and dibromoethane was obtained: b. p. 131-132° (750 mm), n_D^{20} 1.5385.

Literature [10]: b. p. 131-132°, n_D^{20} 1.5380.

Heating of 3 g diethyl ester of hydrazodiformic acid with 3.5 g phosphorus pentoxide as described above led to decomposition with resinification. The evolved gases contained carbon dioxide and ethylene; the latter was detected as the dibromide with b. p. 130-131° and $n^{20}D$ 1.5388.

Hydrogenation of adduct (I). 2 g adduct (I) in 50 ml alcohol was hydrogenated in presence of 0.05 g platinum oxide. 195 ml (N.T.P.) hydrogen was taken up (the theoretical amount is 185 ml). Distillation of alcohol left 2.1 g 3,6-endoxo-1,2-dicarboethoxyhexahydropyridazine in the form of a very viscous, dark oil. When an attempt was made to distill it in vacuo (1 mm) at 180°, an oil came over which crystallized and was identified as the diethyl ester of hydrazodiformic acid: m. p. 131-131.5° (from benzene); no depression in a mixed melting point test with an authentic specimen of the ester.

Adduct (II). 3-Methyl-3,6-endoxo-1,2-dicarboethoxy-Δ^4-tetrahydropyridazine. 16.4 g (0.2 mole) 2-methylfuran in 30 ml absolute ether and 30 g (0.17 mole) diethyl azodiformate in 120 ml absolute ether were reacted as described above to give 42 g of adduct in the form of a transparent, vitreous mass, soluble in alcohol, ether and benzene, insoluble in water, cyclohexane and ligroine.

Found %: C 51.37, 51.41; H 6.33, 6.38; N 11.05, 11.19. M 250, 240 (According to Rast). $C_{11}H_{16}O_5N_2$. Calculated %: C 51.55; H 6.25; N 10.93. M 256.

3-Methyl-3,6-endoxo-1,2-dicarboethoxy-4,5-dibromohexahydropyridazine. Bromination of 2 g adduct (II) as described above gave 2 g dibromo derivative in the form of a yellow, transparent vitreous mass.

Found %: Br 38.58, 38.61. $C_{11}H_{16}O_5N_2Br_2$. Calculated %: Br 38.34.

Diethyl hydrazodiformate from adduct (II). Heating of 2.5 g adduct (II) with 3.5 g phosphorus pentoxide as described above gave diethyl hydrazodiformate with m. p. 131-131.5° (from benzene); a mixed melting test with an authentic specimen of the ester did not give a depression.

Hydrogenation of adduct (II). 2 g adduct (II) in 50 ml alcohol was hydrogenated as described above. 185 ml (N.T.P.) hydrogen was taken up (the theoretical quantity is 175 ml). Removal of the alcohol left 1.9 g 3-methyl-3,6-endoxo-1,2-dicarboethoxyhexahydropyridazine in the form of a dark, viscous oil. Pyrolysis as described above gave diethyl hydrazodiformate with m. p. 131-131.5°; a mixed melting test with an authentic specimen of the ester did not give a depression.

Diethyl ester of N-(2-furoxy)-hydrazodiformic acid. A solution of 30 g (0.17 mole) diethyl azodiformate in 120 ml absolute ether was mixed in an Erlenmeyer flask with 19.6 g (0.2 mole) furfuryl alcohol in 30 ml absolute ether. After completion of the reaction, the ether was allowed to evaporate very slowly. There was obtained 33 g white, finely crystalline powder: m. p. 66.5-67° (from ether).

Found %: C 48.58, 48.49; H 6.04, 6.15; N 10.18, 10.36. $C_{11}H_{16}O_6N_2$. Calculated %: C 48.52; H 5.92; N 10.29.

Introduction into the reaction of double the quantity of diethyl ester led to isolation of the same substance, and there was no depression of melting point in a test with a mixture of both specimens; m. p. 66-67°.

The following frequencies were found in the infrared absorption spectrum of this compound: 720, 766, 806, 844, 870, 942, 1002, 1014, 1032, 1064, 1088, 1148, 1158, 1232-1244, 1302, 1388, 1452, 1518, 1686, 1724, 3264-3293 cm^{-1}. According to the literature [35] the furan ring is associated with the following frequencies: 725, 872, 994, 1139, 1389, 1490 cm^{-1}. Consequently, the 720, 870, 1002, 1148, 1388, 1518 cm^{-1} frequencies are indicative of the presence of a furan ring in the compound; the frequencies in the 3264-3293 cm^{-1} region reflect the presence of the NH group.

Hydrogenation of diethyl ester of N-(2-furoxy)-hydrazodiformic acid. 2 g diethyl ester in 50 ml anhydrous alcohol was hydrogenated in presence of 0.07 g platinum oxide. 350 ml (N.T.P.) hydrogen was taken up (the theoretical quantity for 2 moles H_2 is 329 ml). Removal of the alcohol left 2 g of the diethyl ester of N-(2-tetrahydrofuroxy)-hydrazodiformic acid in the form of a dark, viscous oil. On distillation in vacuo (1 mm) at 180°, the diethyl ester of hydrazodiformic acid came over: m. p. 131-131.5° (from benzene); no melting point depression in admixture with an authentic specimen.

2 g of hydrogenation product was refluxed 2 hours with 40 ml 2 N hydrochloric acid. The dark solution was cooled and 10 ml 30% hydrogen peroxide was added. The mixture was left for 2 hours, then boiled for

0.5 hour, concentrated to 20 ml, boiled with carbon, filtered, and evaporated to 10 ml. Rubbing led to separation of crystals of diethyl hydrazodiformate; m. p. 131-131.5° (from benzene); no depression of melting point in admixture with an authentic specimen.

SUMMARY

1. Furan and 2-methylfuran react with diethyl azodiformate according to the diene synthesis with formation, respectively, of 3,6-endoxo-1,2-dicarboethoxy-Δ^4-tetrahydropyridazine and 3-methyl-3,6-endoxo-1,2-dicarboethoxy-Δ^4-tetrahydropyridazine.

2. Furfuryl alcohol reacts with diethyl azodiformate with formation of diethyl N-(2-furoxy)-hydrazodiformate.

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TETRAACYLOXYSILANES IN ORGANIC SYNTHESIS

XXIV. REACTION OF TETRAACYLOXYSILANES WITH ORGANOMAGNESIUM AND ORGANOCADMIUM COMPOUNDS

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Two types of reactions are characteristic of acyloxysilanes: reactions accompanied by rupture of the $C-O$ bond, and reactions accompanied by rupture of the $Si-O$ bond. The first type include all acylations by tetraacyloxysilanes: acylation of the nucleus of benzene [1], thiophene [2], selenophene [3], pyrrole [4], malonic and acetoacetic ester [5], amines [6, 7].

$$\geqslant C-H + \geqslant Si-O-\underset{\underset{O}{\|}}{C}-R \longrightarrow \geqslant C-\underset{\underset{O}{\|}}{C}-R + \geqslant Si-OH$$

$$\geqslant N-H + \geqslant Si-O-\underset{\underset{O}{\|}}{C}-R \longrightarrow \geqslant N-\underset{\underset{O}{\|}}{C}-R + \geqslant Si-OH$$

Rupture of the $C-O$ bond is also observed in the reaction of tetraacyloxysilanes with acetylene in presence of anhydrous aluminum chloride leading to chlorovinyl ketones; the first step is evidently addition of the tetraacyloxysilane to acetylene [8].

$$HC\equiv CH + \geqslant Si-O-\underset{\underset{O}{\|}}{C}-R \longrightarrow \geqslant Si-O-CH=CH-\underset{\underset{O}{\|}}{C}-R$$

The second type includes reactions of replacement of the acyloxy group by the alkoxy group, as was exemplified by the reaction between butyl alcohol and methyltriacetoxysilane [9], as well as by the reaction of benzoyloxytrichlorosilane with ethyl alcohol [10] in accordance with Eq. (I); it is less likely that these reactions proceed with rupture of the $C-O$ bond, i.e., according to Eq. (II):

$$RO-H + \geqslant Si-OCOR' \longrightarrow \geqslant Si-OR + R'COO-H \tag{I}$$

$$R-OH + \geqslant SiO-COR' \longrightarrow \geqslant SiO-R + R'CO-OH \tag{II}$$

In this connection, it should be added that anhydrides [11] react with alcohols according to Eq. (III).

$$R-\underset{\underset{O}{\|}}{C}-O-\underset{\underset{O}{\|}}{C}-R + H-\overset{18}{O}R' \longrightarrow R-\underset{\underset{O}{\|}}{C}-\overset{18}{O}R' + H-O-\underset{\underset{O}{\|}}{C}-R \tag{III}$$

Interest was therefore attached to a study of the reaction of tetraacyloxysilanes with organomagnesium and organocadmium compounds in view of the theoretical possibility of the reaction proceeding in two directions involving respectively rupture of the $C-O$ or $Si-O$ bond in accordance with (IV) and (V).

$$\text{SiR}'_4 + 4\text{RCOOMeX} \underset{}{\overset{+4\text{R'MeX}}{\rightleftarrows}} \text{Si(O}-\underset{\underset{O}{\|}}{\text{C}}-\text{R)}_4 \xrightarrow{+4\text{R'MeX}} \text{Si(OMeX)}_4 + 4\text{R'COR}$$

$$\downarrow +8\text{R'MeX} \qquad\qquad\qquad\qquad\qquad\qquad \downarrow +\text{H}_2\text{O} \qquad \downarrow +4\text{R'MeX}$$

R'
|
R'—C—R   Si(OH)₄   R'
| 4R'—C—R
OH |
(V)   OH
(IV)

Me = Mg, Cd

We know from the literature that acid anhydrides react with organocadmium compounds in ether at the boil to give ketones [12]; with organomagnesium compounds they also form ketones but only at low temperatures (−50 to −70°) [13, 14]. Alkoxysilanes react with organomagnesium compounds [15] with formation of tetra-alkylsilanes; the latter are also obtained by alkylation of silicon tetrachloride or alkylchlorosilanes with organomagnesium compounds [16].

In 1953-1954, Lanning described a reaction between silicopropionic anhydride [17] and between silico-benzoic anhydride [18] and ethylmagnesium bromide which led only to triethylcarbinol and diethylphenylcarbinol, respectively, apart from an unidentified silicon-containing compound.

In the present work we studied the reaction between silicoacetic anhydride and alkylmagnesium halides; in all cases we obtained tertiary alcohols (58-68.5% yields), tetraalkylsilanes (51-72% yields) and higher boiling fractions which were apparently siloxanes. All of these data, as well as the absence of silicic acid from the reaction products, indicate that the reaction of tetraacyloxysilanes with organomagnesium compounds goes with rupture of the Si−O bond, i.e., according to mechanism (V). With increasing strength of the organic acid entering into the composition of the silicoanhydride, the strength of this bond is lowered and therefore the reactivity of the tetraacyloxysilane with the organomagnesium compound increases.

After the present work had been mainly completed, Lanning and Moore [19] reported the isolation from the product of reaction between tetraacyloxysilanes and ethylmagnesium bromide of tertiary alcohols and of a fraction of ethylsiloxanes with the general formula $[(\text{C}_2\text{H}_5)_2\text{SiO}]x$, where x = 3, 4.

We also effected reaction of silicoacetic anhydride with organocadmium compounds which led to ketones (20 to 46% yields) and silicic acid. In this case, the reaction evidently goes with rupture of the C−O bond, i.e., according to mechanism (IV).

EXPERIMENTAL

I. Reaction of tetraacyloxysilanes with alkylmagnesium halides. The tetraacyloxysilane was prepared from 0.1 mole organic acid and 0.03 mole silicon tetrachloride in 150 ml dry benzene by the method described earlier [7]. Excess of silicon tetrachloride was removed by distillation of 50 ml benzene.

Grignard reagent was prepared (in a flask fitted with stirrer, reflux condenser and dropping funnel) from 0.4 g-atom magnesium and 0.4 mole alkyl halide in 150 ml absolute ether. To this was added the benzene solution of tetraacyloxysilane and the mixture was boiled 18-20 hours. After cooling with ice, the product was decomposed with acidified iced water; the ether layer was separated and the aqueous layer extracted with ether. The combined ether-benzene solution was washed with water, then with sodium carbonate solution and again with water, and dried with anhydrous magnesium sulfate. After the solvents had been distilled off, the residue was fractionally distilled to separate tertiary alcohol and tetraalkylsilane. The latter was redistilled over sodium.

1. Methyldiethylcarbinol and tetraethylsilane. The following compounds were obtained from 6 g acetic acid, 3.4 ml silicon tetrachloride, 9.6 g magnesium and 43.6 g ethyl bromide: a) 6.8 g (66.5%) methyldiethyl-carbinol:

B. p. 121-122° (750 mm), $n^{20}\text{D}$ 1.4202, d^{20}_4 0.8297, MR_D 31.17. $\text{C}_6\text{H}_{14}\text{O}$. Calculated 31.44.

Literature data: b. p. 120-122° [20]; b. p. 122.8-123.0° (760 mm), $n^{25}D$ 1.4166, d^{25}_4 0.8233 [21].

b) 2.5 g (69.5%) tetraethylsilane;

B. p. 152-154° (750 mm), $n^{20}D$ 1.4272, d^{20}_4 0.7637.

Found %: Si 20.00, 19.86. $C_8H_{20}Si$. Calculated %: Si 19.45.

Literature data: b. p. 153.7° (760 mm), $n^{20}D$ 1.4267, d^{20}_4 0.7662 [22].

c) 1.2 g of a fraction with a boiling range of 60-130° (16 mm), apparently a mixture of siloxanes.

2. Methyldipropylcarbinol and tetrapropylsilane. The following compounds were obtained from 6 g of acetic acid, 3.4 ml of silicon tetrachloride, 9.6 g of magnesium and 49.2 g of propyl bromide: a) 8 g (61.5%) of methyldipropylcarbinol:

B. p. 58-59° (10 mm), $n^{20}D$ 1.4275, d^{20}_4 0.8227, MR_D 40.66. $C_8H_{18}O$. Calculated 40.67.

Literature data: b. p. 159.5-160.5°; d^{20}_4 0.82357 [23].

b) 2.8 g (56%) tetrapropylsilane.

B. p. 88-89° (10 mm), $n^{22}D$ 1.4375, d^{20}_4 0.7872.

Found %: Si 13.69, 13.73. $C_{12}H_{28}Si$. Calculated %: Si 14.01.

Literature data: b. p. 90-91.5° (13 mm), $n^{20}D$ 1.4370, d^{20}_4 0.7838 [24].

c) 3.2 g of a fraction with a boiling range of 91-160° (10 mm), apparently a mixture of siloxanes.

3. Methyldibutylcarbinol and tetrabutylsilane. From 6 g acetic acid, 3.4 ml silicon tetrachloride, 9.6 g magnesium and 54.8 g butyl bromide were obtained the following compounds: a) 10.8 g (68.5%) methyl-dibutylcarbinol:

B. p. 85-86° (10 mm), $n^{20}D$ 1.4352, d^{20}_4 0.8305. MR_D 49.74. $C_{10}H_{22}O$. Calculated 49.90.

Literature data: b. p. 91.4-92.4° (15 mm), $n^{20}D$ 1.4341, d^{20}_4 0.8290 [25].

b) 4.6 g (72%) tetrabutylsilane;

B. p. 116-118° (10 mm), $n^{20}D$ 1.4445, d^{20}_4 0.8265.

Found %: Si 10.91, 10.97. $C_{16}H_{36}Si$. Calculated %: Si 10.94.

Literature data: b. p. 105.5-108.8° (5 mm), $n^{20}D$ 1.4462, d^{20}_4 0.8005 [24].

c) 2.4 g of a fraction distilling in the range of 119 to 165° (10 mm), evidently a mixture of siloxanes.

4. Methyldiisoamylcarbinol and tetraisoamylsilane. The following compounds were obtained from 6 g acetic acid, 3.4 ml silicon tetrachloride, 9.6 g magnesium and 60.4 g isoamyl bromide: a) 10.6 g (58%) methyldiisoamylcarbinol:

B. p. 100-101° (9 mm), $n^{20}D$ 1.4385, d^{20}_4 0.8289, MR_D 59.05. $C_{12}H_{26}O$. Calculated 59.14.

Literature data: b. p. 108-109° (10 mm), $d^{12.3}_4$ 0.8373, $n^{12.3}D$ 1.44253 [26].

b) 4 g (51%) tetraisoamylsilane:

B. p. 150-152° (15 mm), $n^{20}D$ 1.4472, d^{20}_4 0.8623.

Found %: Si 8.42, 8.69. $C_{20}H_{44}Si$. Calculated %: Si 8.98.

Literature data: b. p. 275° [27].

c) 5.5 g fraction coming over at 153-180° (15 mm), evidently a mixture of siloxanes.

II. Reaction of tetraacyloxysilanes with organocadmium compounds. Tetraacyloxysilane and Grignard reagent were prepared as described above from the same quantities of reagents. 0.25 mole anhydrous cadmium chloride was added to the ethereal solution of the Grignard reagent and the reaction mixture was boiled until a

test for Grignard reagent was negative. A benzene solution of the tetraacyloxysilane was added to the resulting organocadmium compound and the mixture was boiled 18-20 hours. The product was decomposed with dilute hydrochloric acid (silicic acid was precipitated). Solvent and ketone were distilled off with steam. The benzene-ether layer was separated, washed with water and dried with calcium chloride. After the ether and benzene had been distilled off, the residue was distilled in vacuo.

1. Acetophenone. From 6 g acetic acid, 3.4 ml silicon tetrachloride, 9.6 g magnesium, 60.8 g bromobenzene and 46 g cadmium chloride was obtained 2.4 g (20%) acetophenone:

B. p. 92-93° (20 mm), $n^{20}D$ 1.5342, d^{20}_4 1.0261, MR_D 36.41. $C_8H_8O_{F2}$. Calculated 35.55.

Literature data: b. p. 201-203° (756 mm), d^{20}_4 1.031, $n^{20}D$ 1.5408 [1].

2. Methylbutyl ketone. From 6 g acetic acid, 3.4 ml silicon tetrachloride, 9.6 g magnesium and 54.8 g butyl bromide was obtained 4.6 g (46%) methylbutyl ketone:

B. p. 125-126° (742 mm), $n^{20}D$ 1.3995, d^{20}_4 0.8125, MR_D 29.85. $C_6H_{12}O$. Calculated 29.92. 2,4-Dinitrophenylhydrazone: m. p. 107-108°.

Literature data: b. p. 126°, $n^{20}D$ 1.4001; 2,4-dinitrophenylhydrazone, m. p. 107-108° [28].

SUMMARY

1. Reaction between tetraacyloxysilanes and organomagnesium compounds leads to formation of tertiary alcohols and tetraalkylsilanes.

2. Reaction of tetraacyloxysilanes with organocadmium compounds leads only to ketones and silicic acid.

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ACYL PYRAZOLES

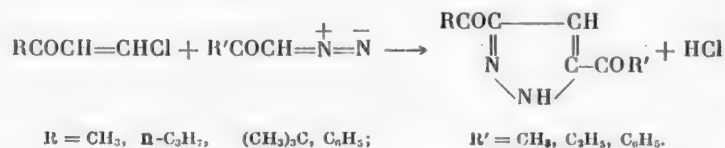III. SYNTHESIS AND ACIDITY CONSTANTS OF 3,5-DIACYLPYRAZOLES

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It was shown in preceding communications [1, 2] that 3-acylpyrazoles exhibit weak but well-marked acidic properties due to the facility of detachment of the hydrogen linked to the nitrogen of the pyrazole ring under the influence of a substituting acyl group [3]. It was also shown [2] that the acidity of 3-aroylpyrazoles containing substituents in the phenyl ring is subject to the same laws as in the corresponding benzoic acids.
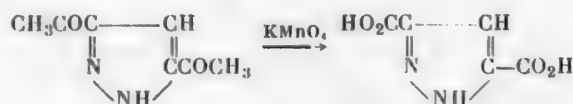
Continuing the investigation of the effect of substituents on the acidity of pyrazole derivatives, we have synthesized the previously unknown 3,5-diacylpyrazoles.

The method of synthesis that we developed was based on reaction of β-chlorovinyl ketones with diazoketones. β-Chlorovinyl ketones are known [4, 5] to react smoothly with diazomethane to form 3-acylpyrazoles. Their reaction with diazoacetic ester leads to 3-acyl-5-carboethoxypyrazoles [5]. Nothing has previously been published about the reaction of diazoketones with α,β-unsaturated carbonyl compounds, except a communication [6] (which appeared while the present work was in progress) on the interaction of diazoketones with some α,β-unsaturated ketones. The latter reaction was utilized for the synthesis of ketones of the cyclopropane series. The reaction of diazoketones with β-chlorovinyl ketones has not previously been investigated. It was found that this reaction goes quite smoothly when the reactants are heated without a solvent at 70-110°. It gives 3,5-diacylpyrazoles in yields of 40-50%. Lower yields were obtained when this reaction was attempted in a solvent such as benzene. All of the β-chlorovinyl ketones react with approximately the same facility; phenyl β-chlorovinyl ketone reacts rather more vigorously. We brought the following β-chlorovinyl ketones into reaction: methyl β-chlorovinyl ketone, propyl β-chlorovinyl ketone, tert-butyl β-chlorovinyl ketone, and phenyl β-chlorovinyl ketone. The diazoketones reacted were diazoacetone, 1-diazo-2-butanone, and ω-diazoacetophenone. Nine 3,5-diacylpyrazoles were prepared. These do not combine with the hydrogen chloride released during the reaction, and are isolated not as the hydrochlorides but as the free bases, in which respect they differ from the 3-acylpyrazoles [2, 5]. This behavior demonstrates the complete loss of the basic properties of the pyrazole ring. The liberated hydrogen chloride brings about partial breakdown of the diazoketone to the ω-chloroketone; we invariably detected small quantities of the latter in the reaction mixture. A slight excess of diazoketone is therefore necessary in order to obtain optimum yields of 3,5-diacylpyrazoles.

$$\text{RCOCH}{=}\text{CHCl} + \text{R}'\text{COCH}{=}\overset{+}{\text{N}}{=}\overset{-}{\text{N}} \longrightarrow \begin{array}{c}\text{RCOC}\text{-----}\text{CH} \\ \underset{\text{N}}{\|} \quad \underset{\text{C-COR}'}{\|} \\ \diagdown\text{NH}\diagup\end{array} + \text{HCl}$$

$$\text{R} = \text{CH}_3, \ \text{n-C}_3\text{H}_7, \ (\text{CH}_3)_3\text{C}, \ \text{C}_6\text{H}_5; \qquad \text{R}' = \text{CH}_3, \ \text{C}_3\text{H}_5, \ \text{C}_6\text{H}_5.$$

The above reaction again emphasizes the general character of the method of synthesis of pyrazole derivatives from β-chlorovinyl ketones and aliphatic diazo compounds.

The structure of the 3,5-diacyl derivatives was verified by the identity between specimens of 3-acetyl-5-benzoylpyrazole prepared by interaction of methyl β-chlorovinyl ketone with ω-diazoacetophenone and by interaction of phenyl β-chlorovinyl ketone and diazoacetone. If 3,4-diacyl derivatives, and not 3,5-derivatives, had been formed, then the compounds prepared by the two methods would not have been identical. Formation of 3,5-substituted pyrazoles is also confirmed by permanganate oxidation of 3,5-diacetylpyrazole to pyrazole-3,5-dicarboxylic acid.

$$\text{CH}_3\text{COC} \underset{\underset{\text{NH}}{\displaystyle\underset{|}{\text{N}}}}{\text{—CH}} \overset{\text{}}{\underset{\text{CCOCH}_3}{\displaystyle\parallel}} \xrightarrow{\text{KMnO}_4} \text{HO}_2\text{CC} \underset{\underset{\text{NH}}{\displaystyle\underset{|}{\text{N}}}}{\text{—CH}} \underset{\text{C—CO}_2\text{H}}{\displaystyle}$$

The relative orientation of the β-chlorovinyl ketone and the diazo compound is therefore subject to the Auwers rule [7] as in the reaction of β-chlorovinyl ketones with diazoketones, diazomethane, and diazoacetic ester [2, 5].

All of the prepared 3,5-diacylpyrazoles are stable, well-crystallized substances completely devoid of the basic properties that are manifested by pyrazole, alkyl- and arylpyrazoles and (to a minor degree) by mono-acylpyrazoles [1, 2, 5]. At the same time they manifest marked acidic properties — they dissolve in aqueous caustic alkali solutions from which they are regenerated by acidification.

We measured the acid dissociation constants of 3,5-diacylpyrazoles, in order to quantitatively evaluate the dependence of the acidity on the nature of the acyl groups. For this purpose, we made use of our earlier [1, 2] spectrophotometric method. The ultraviolet absorption spectra of the investigated compounds were plotted at different pH values of the medium (standard buffer solutions with pH of 6 to 14). The corresponding dissociation constants were then calculated. Due to their substantial insolubility in water, we were unable to obtain the spectra of 3-pivalyl-5-benzoyl- and 3,5-dibenzoylpyrazoles in neutral and nearly neutral media or to calculate the acidity constants of these compounds. The spectra of 3,5-diacylpyrazoles in a neutral medium comprise two bands (Figs. 1 and 2): a short-wave, stronger band with a maximum in the 225-235 mμ region, and a long-wave band with inflection points. The two-band structure of
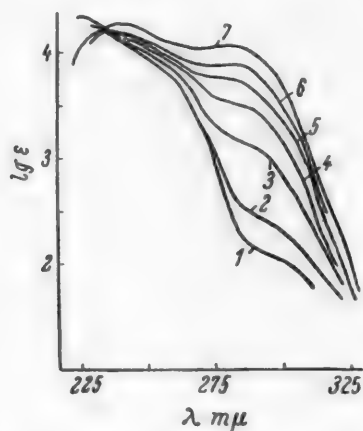
Fig. 1. Ultraviolet absorption spectra of 3,5-diacetylpyrazole; pH values: 1) 6, 2) 7, 3) 8, 4) 8.5, 5) 9, 6) 9.5, 7) 9-14.
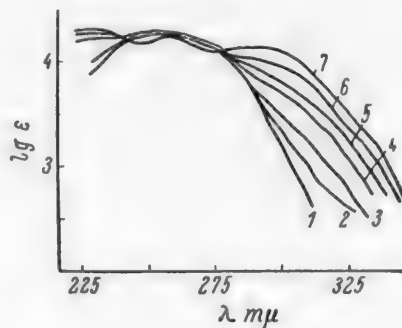
Fig. 2. Ultraviolet absorption spectra of 3-acetyl-5-benzoylpyrazole; pH values: 1) 6, 2) 7, 3) 8, 4) 8, 5) 9, 6) 9.5, 7) 9-14.

the spectrum becomes more pronounced in an alkaline medium and both of the maxima are clearly defined. At the same time, the two bands are shifted to the long-wave side. In an alkaline medium the short-wave band retains its greater intensity. It is interesting to note that two maxima are already observed in a neutral medium in the spectra of phenyl-containing compounds. The spectra of all of the investigated diacylpyrazoles contain one or even several (three) isosbestic points — evidence of an acid-base equilibrium in the solutions of these compounds.

Dissociation constants were calculated with the help of the formula of Stenström and Goldsmith [8].*

The spectrophotometric data and results of calculation of the dissociation constants for 3,5-diacylpyrazoles are presented in Table 1.

TABLE 1

Substance	λ_{max} (in mμ)		λ of isosbestic point	pK
	neutral medium	alkaline medium		
3,5-Diacetylpyrazole	224	242, 280	235	8.98
3-Acetyl-5-benzoylpyrazole	230, 263	252, 290	242, 261, 277	9.01
3-Acetyl-5-propionylpyrazole	230	243, 277	229	9.05
3-Propionyl-5-benzoylpyrazole	234, 261	250, 282	236, 270	9.14
3-Acetyl-5-butyrylpyrazole	228	245, 273	233	9.28
3-Acetyl-5-pivalylpyrazole	227	242, 276	235	9.70
3-Propionyl-5-pivalylpyrazole	227	243, 275	233	9.70
3-Pivalyl-5-benzoylpyrazole	—	257, 290	—	—
3,5-Dibenzoylpyrazole	—	255, 297	—	—

We see from the data of Table 1 that all of the prepared 3,5-diacylpyrazoles are approximately 500-1000 times stronger as acids (pK 9-9.7) than the 3-acylpyrazoles (pK 11.7-12.5) [1, 2] since the introduction of a second acyl group intensifies to a considerable extent the susceptibility to proton release from the nitrogen of the pyrazole ring. The two acyl groups act congruently.
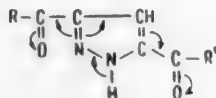
Table 1 also reveals a clear dependence of the acidity constants of the different diacylpyrazoles on the nature of the acyl radicals. It was to be expected that increasing magnitude of the positive inductive effect inherent in the radicals R and R' would be accompanied by weakening of the acidic properties of the respective diacylpyrazoles. A comparison of the 3-acetyl-5-acylpyrazoles (R = CH$_3$) actually shows that the dissociation constants decrease with changing R' in the order

$$CH_3 > C_2H_5 > \text{н.-}C_3H_7 > (CH_3)_3C,$$

This sequence is in complete accord with the well-known order of rise of the positive inductive effect for these radicals. This behavior is also consistent with our earlier observation [1] of the lower acidity of 3-pivalyl-pyrazole in comparison with that of 3-acetylpyrazole. The acidity of 3,5-diacylpyrazoles is consequently subject to the laws that govern the strength of the corresponding carboxylic acids, as we also observed in the case of 3-aroylpyrazoles [2]. Our quantitative results demonstrate that the nature of the acidity of nitrogen-containing heterocycles does not differ in principle from the acidity of ordinary organic acids even though in the former case a proton is split off from the aromatic system.

EXPERIMENTAL

Methyl, propyl, tert-butyl and phenyl β-chlorovinyl ketones were prepared by known methods [9, 10].

Diazoacetone and ω-diazoacetophenone were prepared by the procedure described in [11].

* See Communication II.

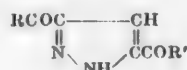1-Diazo-2-butanone* was obtained from a dried solution of diazomethane (from 40 g nitrosomethylurea in 450 ml ether) and a solution of 8.2 g propionyl chloride in 70 ml dry ether. Yield 53%. 1-Diazo-2-butanone is a dark-yellow oil with an aromatic odor; b. p. 48-50° (12 mm), n_D^{20} 1.4832.

3,5-Diacylpyrazoles. A mixture of 0.02 mole β-chlorovinyl ketone and 0.026 mole diazoketone was heated for several hours in a flask fitted with a reflux condenser. A little gas was usually evolved. The reaction mixture gradually darkened and at the end of the reaction crystals of the 3,5-diacylpyrazoles were deposited. After cooling, these were pressed on the filter and washed with a little dry ether. Another crop of crystals could be separated from the filtrate. The substance was purified by recrystallization first from benzene or ligroine and then from water. Reaction conditions, yields and constants of the preparations are set forth in Table 2.

TABLE 2

Synthesized 3,5-Diacylpyrazoles

$$RCOC-\!\!\!\!\overset{\displaystyle \|}{\underset{\displaystyle N}{}}\!\!\!\!\!\overset{\displaystyle CH}{\underset{\displaystyle NH}{}}\!\!\!\!\overset{\displaystyle \|}{CCOR'}$$

R	R'	Reaction conditions		Yield (in %)	Melting temperature	% C		% H		% N	
		dura-tion (hr)	temp.			found	calc.	found	calc.	found	calc.
CH₃	CH₃	3.5	80°	42	148—149.5°	55.35, 55.26	55.26	5.76, 5.59	5.30	18.73, 18.61	18.41
CH₃	C₆H₅	5	105	52	125.5—126.5	67.40, 67.34	67.27	4.92, 4.79	4.70	—	—
C₆H₅	CH₃	4	80	62	125—126	—	—	—	—		
CH₃	C₂H₅	6	75	47	129.5—131	—	—	—	—	16.75, 16.54	16.86
C₆H₅	C₂H₅	4	80	53	137—139	—	—	—	—	12.52, 12.17	12.28
n-C₃H₇	CH₃	4	85	33	108.5—110.5	60.10, 60.06	59.98	6.71, 6.87	6.72	—	—
(CH₃)₃C	CH₃	4	85	50	144—146	—	—	—	—	14.34, 14.18	14.43
(CH₃)₃C	C₂H₅	4	85	50	113—115	63.75, 63.75	63.44	7.99, 7.92	7.75	—	—
(CH₃)₃C	C₆H₅	3	115	37	95.5—98.5	—	—	—	—	11.61, 11.44	10.93
C₆H₅	C₆H₅	4	80	81	150.5—152	74.09, 73.91	73.90	4.65, 4.78	4.38	—	—

Solutions were made up and spectra were plotted as described in the preceding communication.

Of the curves obtained we present those of 3,5-diacetylpyrazole (Fig. 1) and 3-acetyl-5-benzoylpyrazole (Fig. 2) in media with various pH values. The spectra of the remaining diacylpyrazoles are similar.

SUMMARY

1. A general method of synthesis of previously unknown 3,5-diacylpyrazoles is developed on the basis of reaction of β-chlorovinyl ketones with diazoketones (yields of 40-50%).

2. The ultraviolet absorption spectra of the 3,5-diacylpyrazoles were plotted at various pH values and the acid dissociation constants were calculated.

3. It was shown that the introduction of a second acyl group into the pyrazole ring increases the acidity of the acylpyrazole by a factor of 500-1000.

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* Prijs, Ostertag and Erlenmeyer [12] described the synthesis of 1-diazo-2-butanone but they did not isolate the pure substance.

4. It was shown that the acidity of diacylpyrazoles depends on the nature of the radical of the acyl group. It decreases in the order: $CH_3 > C_2H_5 > n-C_3H_7 > (CH_3)_3C$. This corresponds to the order of increasing positive inductive effect of these radicals. The inference that the acidity of acylpyrazoles is subject to the same laws as the acidity of other organic acids is confirmed [2].

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* Original Russian pagination. See C. B. Translation.

THE HYDROGENATION OF FURAN COMPOUNDS OVER METALS

VIII. THE EIGHTH GROUP OF THE PERIODIC SYSTEM

N. I. Shuikin, I. F. Bel'skii, and Kh. M. Minachev

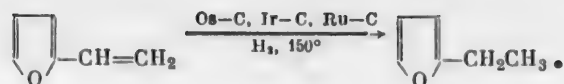Institute of Organic Chemistry of the Academy of Sciences, USSR

Two parallel reactions can take place during hydrogenation of the furan ring: hydrogenation of the double bonds in the ring with formation of tetrahydrofuran derivatives, and hydrogenolysis of the ring in various directions leading to alcohols, ketones or hydrocarbons of the aliphatic series. Whether one of these reactions proceeds predominantly or exclusively will depend on the conditions — mainly the temperature and the type of catalyst.

Ring hydrogenolysis is favored by rising temperature; consequently, if a catalyst under specific conditions possesses activity for both of the reactions (for example, skeletal Ni − Al in the vapor phase), then by choosing a suitable temperature one can with a high degree of selectivity steer the hydrogenation of the furan ring in the direction of one of these reactions. A more powerful weapon than temperature adjustment for selective hydrogenation of the furan ring is the application of specific catalysts. The majority of catalysts investigated in the hydrogenation of furan compounds contain metals of the eighth group of the Periodic System. Judging by the literature data, some metals of the eighth group under certain comparable conditions promote hydrogenolysis of the furan ring either preferentially or exclusively; others promote hydrogenation of the ring double bonds. The properties of the catalysts can be compared if other reaction conditions remain unchanged, since it was established that a given catalyst can steer the hydrogenation of the furan ring in different directions depending on whether or not the reaction is performed in the liquid or gas phase. For example, nickel-on-zinc oxide catalyzes hydrogenation of 2-methylfuran in an autoclave to tetrahydro-2-methylfuran [1], while at 250° in the gas phase it catalyzes only ring hydrogenolysis at the C − O bond not adjacent to the alkyl radical [2]. On the other hand, skeletal Ni − Al catalyzes the hydrogenation of the ring double bonds both in the liquid and vapor phase at temperatures not exceeding 150-200° [3].
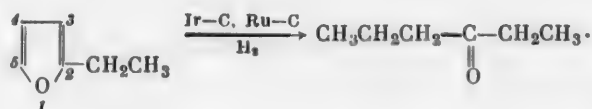
Platinum and palladium exhibit marked differences as furan ring hydrogenation catalysts. These two metals, deposited on active carbon, were investigated for the hydrogenation of 2-methylfuran in the vapor phase at 275° and normal pressure. In presence of Pt − C, 2-methylfuran underwent complete hydrogenolysis at the C − O bond on the 1,5-side with formation of methyl propyl ketone; over Pd − C the degree of ring hydrogenolysis in the same direction was only 20-25%, and the main reaction was hydrogenation of the ring double bonds [4]. Rhodium-on-carbon, under vapor phase conditions, promotes both hydrogenation of the furan ring double bonds (40%) and ring hydrogenolysis at the 1-5 C − O bond (60%); only hydrogenolysis of the ring takes place over Rh − C at 300° [5].

The results of preceding investigations raised the question as to which of the metals of the eighth group are capable, like palladium, of steering the hydrogenation of a wide temperature region preferentially in the direction of the furan ring, and which, like platinum, are more active in furan ring hydrogenolysis.

We have investigated the catalytic properties of osmium, iridium, and ruthenium, all deposited on carbon, in the hydrogenation of 2-methylfuran and α-vinylfuran in the vapor phase at various temperatures. At 150° over all of these catalysts, α-vinylfuran is hydrogenated to α-ethylfuran in yields of 95-100%.
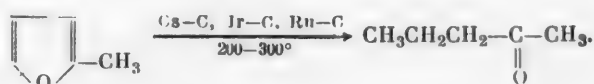
$$\text{[furan-CH=CH}_2\text{]} \xrightarrow[\text{H}_2,\ 150°]{\text{Os-C, Ir-C, Ru-C}} \text{[furan-CH}_2\text{CH}_3\text{]} \cdot$$

A very small proportion (about 5%) of the α-ethylfuran formed undergoes hydrogenolysis at the 1-5 C $-$ O bond over Ir $-$ C and Ru $-$ C.

$$\text{[furan-CH}_2\text{CH}_3\text{]} \xrightarrow[\text{H}_2]{\text{Ir-C, Ru-C}} \text{CH}_3\text{CH}_2\text{CH}_2-\underset{\underset{O}{\|}}{C}-\text{CH}_2\text{CH}_3 \cdot$$

Formation of ketone was not observed over Os $-$ C at this temperature. An interesting fact must be mentioned at this point. Osmium-on-asbestos is known to be a top catalyst for hydrogenation of the furan ring at low temperatures [6]. Our preparation of osmium-on-carbon turned out to be completely inactive for hydrogenation of the ring double bonds; at 150° only the double bond in the side chain of α-vinylfuran was hydrogenated. Os $-$ C, Ir $-$ C and Ru $-$ C are therefore highly selective for the hydrogenation of the olefinic bond in the side chain of alkenylfuran, the furan ring remaining substantially intact. As we showed earlier [5], platinum and rhodium, deposited on carbon, possess the same properties at this temperature.

The hydrogenation of 2-methylfuran over Os $-$ C, Ir $-$ C and Ru $-$ C at higher temperatures shows that these catalysts are entirely inactive for reduction of the furan ring but exclusively promote hydrogenolysis of the ring at the 1-5 C $-$ O bond with formation of methyl propyl ketone (2-pentanone).

$$\text{[furan-CH}_3\text{]} \xrightarrow[\text{200-300°}]{\text{Os-C, Ir-C, Ru-C}} \text{CH}_3\text{CH}_2\text{CH}_2-\underset{\underset{O}{\|}}{C}-\text{CH}_3 \cdot$$

Depending on the temperature and the rate of passage of the compounds, the catalyzates contain various ratios of 2-methylfuran (unreacted) to methyl propyl ketone. Over Ir $-$ C at 200° and a space velocity of 0.1 hr^{-1}, 2-methylfuran gives about 60% 2-pentanone, while at 275° and the same space velocity substantially the whole of the 2-methylfuran is transformed into 2-pentanone. Over Os $-$ C and Ru $-$ C at 275° and otherwise identical conditions, 2-methylfuran is converted to 2-pentanone to the extent of 40 and 85%, respectively. In no instance was tetrahydro-2-methylfuran formed.

The results obtained earlier and in the present work enable us to draw the following general conclusions. All catalysts containing metals of the eighth group, deposited on carbon, can be arranged into two groups in respect to their action in vapor phase hydrogenation of the furan ring under comparable temperature conditions.

1. Catalysts of the platinum type (Pt, Os, Ir, Ru, Rh) do not catalyze, or only weakly catalyze, the hydrogenation of the furan ring double bonds. Only hydrogenolysis of the furan ring at the C $-$ O bond (1,5-position) takes place over these catalysts at 200-300°.

2. Catalysts of the palladium type (Pd) smoothly hydrogenate the double bonds in the furan ring over a fairly wide temperature range. Their steering of the reaction in the direction of ring hydrogenolysis is only manifested at elevated temperatures.

The arbitrary character of this catalyst classification must be stressed.

Depending on the reaction temperature any of the catalysts can influence the furan ring either like platinum or palladium. At 300° Rh $-$ C, for example, belongs to the platinum type of catalyst; at 200° it occupies an intermediate position since it catalyzes hydrogenation and hydrogenolysis of the furan ring at this temperature. On the other hand, catalysts like Ir $-$ C and Ru $-$ C retain the properties of catalysts of the platinum type at all of the temperatures investigated. The same is true of nickel catalysts on various carriers. At temperatures not higher than 120-150°, skeletal Ni $-$ Al resembles palladium in fairly smoothly catalyzing the hydrogenation of the furan ring [3], but at higher temperatures (235-275°) it catalyzes only what is known as the "conjugated" hydrogenolysis of the furan ring [7]. In contrast to this behavior, nickel on zinc oxide behaves like the platinum type of catalyst at all temperatures [2]. All this shows that some catalysts can belong to both the platinum and

the palladium group according to the reaction temperature. Such a dependence does not apply to other catalysts. The cause of this interesting fact is still unexplained and requires special investigation.

EXPERIMENTAL

Starting substances. 2-Methylfuran was isolated from the technical product by fractional distillation in an efficient column: b. p. 62-64°, d^{20}_4 0.9120, $n^{20}D$ 1.4315. α-Vinylfuran was synthesized by the following reactions:
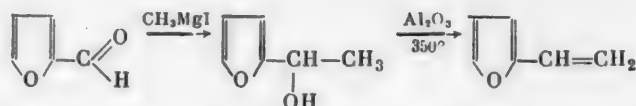
On distillation in a 40-plate (approximately) column, α-vinylfuran boiled at 98-99.5° (755 mm) and had d^{20}_4 0.9487 and $n^{20}D$ 1.5010.

Catalysts. Osmium-on-carbon was prepared by impregnating active carbon with an aqueous solution of OsO_4 (2 g OsO_4 dissolved in 50 ml water at 70°) and treating the mass with formalin and 50% potassium hydroxide solution at first at room temperature and later with heating on a water bath. Excess of potassium hydroxide was neutralized with dilute hydrochloric acid (test by reaction to Congo paper), and then the catalyst was washed with water and dried at 120°.

Ir−C and Ru−C, containing respectively 10 and 15% finely dispersed metal, were also prepared by impregnation of active carbon with the calculated quantities of H_2IrCl_6 and $RuCl_4$ solutions. Further procedure was the same as for preparation of Os−C.

Experimental procedure. 2-Methylfuran and α-vinylfuran were hydrogenated in a flow system at normal pressure using an excess of electrolytic hydrogen. 50 ml catalyst was placed in a quartz tube through which hydrogen was then passed for 3 hours at 250-300°. The catalyst was thereupon cooled to the temperature of the reaction. The temperature was measured with a chromel-alumel thermocouple in the middle of the catalyst bed. The starting substance was admitted into the tube with a space velocity of 0.1 hour^{-1}. The catalyzates were dried with calcium chloride and fractionated in a 40-plate (approximately) column.

Hydrogenation of α-vinylfuran. In each experiment we took 30 g α-vinylfuran and this was hydrogenated over Os−C, Ir−C, and Ru−C at 150°. The catalyzates (yield nearly quantitative) contained α-ethylfuran: b. p. 91-92°, d^{20}_4 0.9018, $n^{20}D$ 1.4402. On Ir−C and Ru−C a small portion of the α-ethylfuran also underwent hydrogenolysis (approximately 5%) with formation of 3-hexanone; the latter was contained in a small 120 to 125° fraction and was identified as the semicarbazone with m. p. 110°.

Hydrogenation of 2-methylfuran. 2-Methylfuran was hydrogenated over Ir−C at 200 and 275°. The catalyzate obtained at 200° contained about 60% methyl propyl ketone (2-pentanone) and unreacted 2-methylfuran, while at 275° substantially the whole of the 2-methylfuran was converted into 2-pentanone. Ru−C exhibited similar activity: at 275° 85% of the 2-methylfuran was converted into 2-pentanone. Os−C was much less active: the products of hydrogenation of 2-methylfuran at 275° contained only 40% 2-pentanone and unreacted 2-methylfuran.

SUMMARY

Vapor phase hydrogenation of α-vinylfuran over Os−C, Ir−C, and Ru−C at 150° results only in saturation of the double bond in the side chain; α-ethylfuran is formed in yields of 95-100%. Over Ir−C and Ru−C a small portion of the α-ethylfuran (approximately 5%) undergoes hydrogenolysis to 3-hexanone.

At higher temperatures Os−C, Ir−C and Ru−C only catalyze the hydrogenolysis of the ring at the C−O bond (1,5-position). 2-Methylfuran at 275° is converted to 2-pentanone over these catalysts to various extents.

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INTERACTION OF PROPYLENE OXIDE WITH SOME COMPOUNDS
CONTAINING AN ACTIVE CHLORINE ATOM

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The α-oxide ring is known to be easily cleaved under the action of various compounds containing an active halogen atom (hydrogen halides or organic and inorganic acid chlorides). Cleavage of the ring of unsymmetrical α-oxides can lead theoretically to two isomeric products depending on the nature of both R and R'.
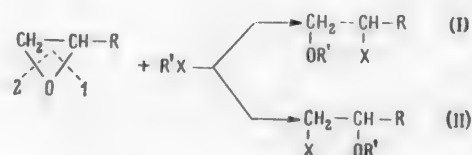
Propylene oxide with hydrochloric acid gives exclusively 1-chloro-2-propanol (II) whereas isobutylene oxide is cleaved in both directions but predominantly (to the extent of 2/3) in the direction of (II) [1]. Chlorides of inorganic acids, such as arsenic trichloride [2], sulfuryl chloride [3], silicon tetrachloride and alkylchlorosilanes [4], open the α-oxide ring in the direction of (I). But if the side chain carries a chlorine atom adjacent to the α-oxide ring, as in the case of epichlorohydrin, then cleavage goes in the direction of (II) on interaction with arsenic trichloride [2] and alkylchlorosilanes [5].

Two types of reactions with compounds containing an active halogen atom are known in the case of γ-oxides (tetrahydrofurans). Like alkylene oxides, γ-oxides can be cleaved at a C—O bond with formation of γ-haloalkoxy derivatives. The other possibility is elimination of the oxygen atom of the γ-oxide with formation of 1,4-dihaloalkanes.

Acyl halides [6] react with γ-oxides by the first route, the same is true (under certain conditions) of silicon tetrachloride and alkyltrichlorosilanes [7]; most of the reactions with hydrogen halides [8], phosphorus tribromide, aluminum chloride, antimony pentachloride [9], phosphine [10] and alkyldichlorosilanes [7] follow the second route.

Some halogen compounds (silicon tetrachloride and alkyltrichlorosilanes) thus react identically with α- and γ-oxides; others (hydrogen halides) open the α-oxide ring at one C—O linkage with carry-over of the oxygen atom of the α-oxide into the molecule of formed product; others again cleave the α-oxide ring at both of the C—O linkages with formation of 1,4-dihalo derivatives. In this connection, interest is attached to a study of the behavior of γ-oxides in reactions with various compounds containing an active halogen atom.

In the present work we studied the reaction of propylene oxide with aluminum chloride, titanium tetrachloride and phosphorus trichloride. We previously studied the reaction of the first two substances with tetrahydro-2-methylfuran [9] so that we can now compare their action on α- and γ-oxides.
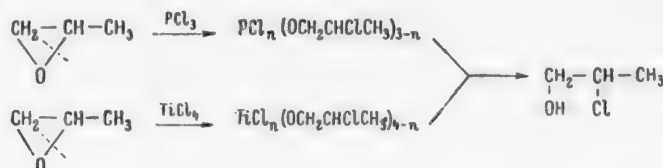
The products of reaction of propylene oxide with $AlCl_3$, $TiCl_4$, and PCl_3 broke down on distillation even at reduced pressure; they were therefore subjected to hydrolysis. The following facts were established by analysis of the products:

1. Reaction of aluminum chloride with propylene oxide goes in similar fashion to the reaction with tetra-hydro-2-methylfuran; 1,2-dichloropropane is formed:
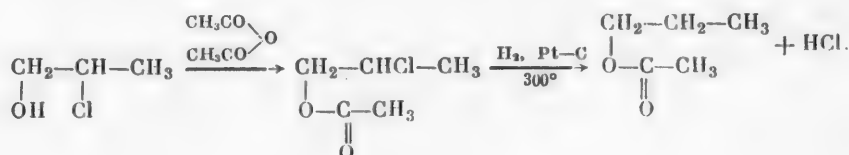
$$CH_2—CH—CH_3 \xrightarrow{AlCl_3} CH_2—CH—CH_3$$
$$\underset{Cl}{|} \quad \underset{Cl}{|}$$

Chlorohydrin was absent from the hydrolysis products.

2. Phosphorus trichloride and titanium tetrachloride open propylene oxide at the $C—O$ linkage adjacent to the methyl group to give unstable chloro-substituted esters of phosphorus and titanic acids. Hydrolysis of these esters leads to 2-chloro-1-propanol:

$$CH_2—CH—CH_3 \xrightarrow{PCl_3} PCl_n(OCH_2CHClCH_3)_{3-n}$$
$$CH_2—CH—CH_3 \xrightarrow{TiCl_4} TiCl_n(OCH_2CHClCH_3)_{4-n} \longrightarrow CH_2—CH—CH_3$$
$$\underset{OH}{|} \quad \underset{Cl}{|}$$

Proof of the structure of the chlorohydrin obtained by hydrolysis was obtained by its conversion to the acetate and subjection of the latter to reductive dehalogenation in the vapor phase over Pt—C at 300°; the latter reaction went extremely smoothly with quantitative yield of propyl acetate:

$$CH_2—CH—CH_3 \xrightarrow[CH_3CO]{CH_3CO\diagdown O} CH_2—CHCl—CH_3 \xrightarrow[300°]{H_2, Pt—C} \underset{O—C—CH_3}{CH_2—CH_2—CH_3} + HCl.$$
$$\underset{OH}{|} \quad \underset{Cl}{|} \qquad \underset{O—C—CH_3}{|} \qquad \qquad \underset{O}{\|}$$

This method of confirming the structure deserves preference over the usual oxidation method.

Reaction of titanium tetrachloride with tetrahydro-2-methylfuran leads, as we know, to cleavage of the γ-oxide ring with elimination of oxygen and formation of 1,4-dichloropentane.

The action of PCl_3 and $TiCl_4$ on the α-oxide ring is therefore entirely similar to that of other acid chlorides of inorganic acids such as $AlCl_3$ and $SiCl_4$. It should be pointed out that although the action of $AlCl_3$ on α-oxides is qualitatively identical with the action on γ-oxides, there is a marked quantitative difference in behavior: tetrahydro-2-methylfuran forms 1,4-dichloropentane in a yield of about 60%, but reaction with propylene oxide gives 1,2-dichloropropane in a yield not exceeding 10% (most of the reaction products have a high boiling point).

EXPERIMENTAL

Propylene oxide (2 moles) was placed in a three-necked flask fitted with a mechanical stirrer, reflux condenser and dropping funnel (capped by a calcium chloride tube); the flask was cooled with a mixture of dry ice and acetone to −30° during reaction with $AlCl_3$ and to −60° during reaction with $TiCl_4$; reaction with PCl_5 was performed at room temperature. Aluminum chloride was added portionwise to the reaction flask, and PCl_3 and $TiCl_4$ were added from the dropping funnel. The amount of these reactants was 1.5 moles. After the whole of the halide had been added (in about 3 hours), the reaction mixture was heated 1 hour on a water bath and then hydrolyzed. Hydrolysis was effected by dropwise addition of 500 ml water after 300 ml ether had been poured into the ice-cooled flask. The mass was stirred vigorously during addition of the water. The reaction mixture was thereupon heated at the boil for 4-5 hours and the ether layer was separated from the aqueous layer. The solid deposit in the flask was extracted 2-3 times with ether and the combined ether extracts

were washed with sodium carbonate solution and dried with potassium carbonate. After distillation of the ether, the products of hydrolysis were fractionated in a glass-packed 20-plate (approximately) column.

1,2-Dichloropropane (approximately 10%) was isolated from the products of reaction of propylene oxide with aluminum chloride: b. p. 95-97° (755 mm), d^{20}_4 1.1516, $n^{20}D$ 1.4380. Higher boiling substances also came over but were not investigated. Hydrolysis of the products of reaction of propylene oxide with phosphorus trichloride and titanium tetrachloride gave 2-chloro-1-propanol in a yield of 70-85% calculated on the original oxide.

B. p. 129-131° (748 mm), $n^{20}D$ 1.4405. 2-Chloro-1-propanol was acetylated by the procedure described in Bayer's textbook [11]. 2-Chloro-1-propyl acetate boiled at 151-152° (745 mm) and had d^{20}_4 1.0950 and $n^{20}D$ 1.4223.

Reductive dehalogenation of 2-chloro-1-propyl acetate was effected by passing it in admixture with hydrogen over 10% platinized carbon at 300°. The catalyzate was washed with sodium carbonate solution, separated from the aqueous layer (from which the reduction products had been extracted with ether), and dried with sodium sulfate. Distillation of the catalyzate from a glass-packed column gave: propyl acetate (60%), with b. p. 100-101° (750 mm), d^{20}_4 0.8906, $n^{20}D$ 1.3835, and some original 2-chloro-1-acetoxypropane.

SUMMARY

Phosphorus trichloride and titanium tetrachloride open the propylene oxide ring at the bond between the oxygen atom and the carbon atom carrying the alkyl group. Hydrolysis of the resulting unstable chloro-substituted esters of phosphorous and titanic acids gave 2-chloro-1-propanol in 70-85% yield.

Aluminum chloride cleaves the propylene oxide ring with elimination of the oxygen atom and formation of 1,2-dichloropropane in a yield not exceeding 10%.

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SYNTHESIS OF BICYCLO-(2,2,2)-OCTANE AND 2-METHYL-3-ETHYL-BICYCLO-(2,2,2)-OCTANE

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The first of the above compounds has already been synthesized by various workers [1-3]; the second has not been described in the literature. We synthesized them by pyrolysis of the acetates of the corresponding alcohols followed by hydrogenation of the resulting unsaturated hydrocarbons. As we know, the pyrolysis of acetates, although taking place at 400-500°, does not result in isomerization of the skeleton of the original compound and it enables preparation of hydrocarbons of the given structure. It was of interest to examine the behavior under these conditions of derivatives of bicyclo-(2,2,2)-octane which are susceptible to loss of one of the bicyclooctane bridges. It was found that our proposed route could lead to a bicyclo-(2,2,2)-octane whose properties agreed with those described in the literature. This justified the conclusion that our synthesized 2-methyl-3-ethylbicyclo-(2,2,2)-octane also possesses the structure that we assign to it.

Reaction steps in the synthesis of bicyclo-(2,2,2)-octane:
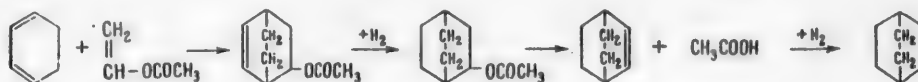
2-Methyl-3-ethylbicyclo-(2,2,2)-octane was synthesized by the following steps:
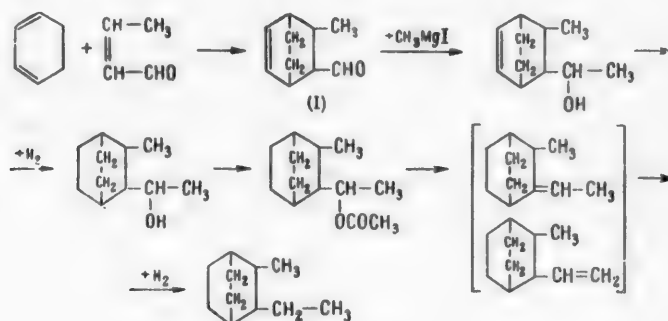
EXPERIMENTAL

Bicyclo-(2,2,2)-octane. Equimolar quantities of 1,3-cyclohexadiene and vinyl acetate were heated 45 hours in a sealed ampoule at 150-160°. There was obtained 30% of the acetate of bicyclo-(2,2,2)-octenol with admixture of about 5% of the dimer of 1,3-cyclohexadiene which could not be separated. The mixture of these substances (b. p. 81-82° at 6 mm) was hydrogenated in a hydrogenation flask, and the saturated product was passed with a space velocity of 0.1 hour^{-1} in a stream of CO_2 through a quartz tube packed with glass wool and

heated to 400°. The reaction product was collected in a receiver cooled with a mixture of dry ice and acetone. 8.6 g of the collected crystals were dissolved in ether, the ethereal extract was dried, and the bicyclooctene was again isolated from the solution by freezing. The crystals were sublimed to give 4.4 g bicyclo-(2,2,2)-octene with m. p. 113-114°

Found %: C 88.77; H 11.03, 11.24. C_8H_{12}. Calculated %: C 88.88; H 11.12.

The hydrocarbon was hydrogenated in a hydrogenation vessel at room temperature in presence of skeletal nickel: m. p. 169-170° (in a sealed capillary). Literature [3]: m. p. 170-171°. Very volatile.

2.2 g of the acetate was hydrolyzed with a solution of potassium hydroxide in methanol with heating. The solid product (1.4 g) was recrystallized from aqueous alcohol; it sublimed at 170° in a sealed capillary and decomposed at 190°.

Found %: C 76.25, 76.30; H 11.64, 11.55. $C_8H_{14}O$. Calculated %: C 76.15; H 11.18.

Phenylurethane: m. p. 133.5-134.5° (from a 110-130° gasoline fraction).

Found %: N 5.60, 5.47. $C_{17}H_{19}O_2N$. Calculated %: N 5.75.

2-Methyl-3-ethylbicyclo-(2,2,2)-octane. 100 g 1,3-cyclohexadiene and 90 g crotonaldehyde were heated 22 hours in a sealed ampoule at 180-190° (yield 60%). Aldehyde (I), prepared in this manner and purified through the semicarbazone (m. p. 173-174°), had the following constants:

M. p. 88-90° (12 mm), $n^{20}D$ 1.4945, d^{20}_4 0.9953, MR_D 43.17. $C_{10}H_{14}O$F. Calculated 45.52.

Grignard reaction of the aldehyde with CH_3MgI (5 g Mg + 30 g CH_3I) gave the secondary alcohol (yield 73%).

B. p. 110-111° (9 mm), 106-107° (7 mm), $n^{20}D$ 1.5040, d^{20}_4 0.9920, MR_D 49.63. $C_{11}H_{18}O$F. Calculated 49.65.

Found %: C 79.45, 79.50; H 10.91, 10.94. $C_{11}H_{18}O$. Calculated %: C 74.48; H 10.89.

The unsaturated alcohol was hydrogenated in presence of skeletal nickel. The saturated alcohol had:

B. p. 108° (7 mm), $n^{20}D$ 1.4962, d^{20}_4 0.9825, MR_D 50.05. $C_{11}H_{20}O$. Calculated 50.11.

Found %: C 78.66, 78.58; H 11.97, 12.06. $C_{11}H_{20}O$. Calculated %: C 78.54; H 11.95.

The acetate was obtained from the alcohol, as described in [4], by the action of acetic anhydride and phosphoric acid:

B. p. 111-112° (3 mm), $n^{20}D$ 1.4762, d^{20}_4 0.9925; MR_D 59.78. $C_{13}H_{22}O_2$. Calculated 59.42.

Found %: C 74.50, 74.40; H 10.50, 10.52. $C_{13}H_{22}O_2$. Calculated %: C 74.24; H 10.54.

The acetate was pyrolyzed under the conditions described above. The unsaturated hydrocarbon (yield 70%) had:

B. p. 183-184° (753 mm), $n^{20}D$ 1.4900, d^{20}_4 0.9000, MR_D 48.36. $C_{11}H_{18}$F. Calculated 48.13.

Found %: C 88.09, 88.12; H 11.85, 11.94. $C_{11}H_{18}$. Calculated %: C 87.96; H 12.04.

The hydrocarbon was hydrogenated in presence of platinum black in a hydrogenation vessel:

B. p. 192-193° (742 mm), $n^{20}D$ 1.4670, d^{20}_4 0.8740, MR_D 48.34. $C_{11}H_{20}$. Calculated 48.60.

Found %: C 86.80, 86.86; H 13.13, 13.22. $C_{11}H_{20}$. Calculated %: C 86.98; H 13.02.

SUMMARY

Bicyclo-(2,2,2)-octane and 2-methyl-3-ethylbicyclo-(2,2,2)-octane were synthesized by pyrolysis of the acetates of the corresponding alcohols.

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THE CHLORINATION OF α-CHLOROALDEHYDES

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The chlorination of aromatic aldehydes to the corresponding acid chlorides has been closely studied [1] but the chlorination of aliphatic aldehydes has been inadequately studied. Only a few instances of replacement of the carbonyl hydrogen of aliphatic aldehydes by chlorine have been described. Chlorination of anhydrous acetaldehyde in sunlight gave acetyl chloride [2]. There is also a patent on preparation of acetyl chloride by chlorination of acetaldehyde in glacial acetic acid solution [3]. Acid chlorides are also formed by a radical type exchange reaction between aldehydes and carbon tetrachloride in presence of benzoyl peroxide [4].

During chlorination of carbonyl compounds the halogen replaces the hydrogen at the carbon in the α-position to the carbonyl. In this connection, it was of interest to study the chlorination of some α-chloro-substituted aldehydes.

Chlorination of dichloroacetaldehyde and α,α-dichloropropionaldehyde in ultraviolet light and in presence of acetylcyclohexanesulfonyl peroxide at 50-60° gave good yields of dichloroacetyl chloride and α,α-dichloropropionyl chloride, respectively. Chlorination of α,α-dichloropropionaldehyde is accompanied by appreciable decarbonylation which is intensified with rising temperature. 1,1,1-Trichloroethane was isolated from the gaseous products of chlorination, and phosgene was detected.

By analogy with the peroxide-catalyzed [4] chain decomposition of aldehydes, the formation of the above products may be represented by the equation

$$R'CCl_2CHO + R \cdot \longrightarrow R'CCl_2\dot{C}O + RH,$$

where $R \cdot = H, CH_3$; $R \cdot$ is a free radical resulting from breakdown of the peroxide or from photolysis of the aldehyde. It can also be a chlorine atom. α,α-Dichloroacyl radicals react with chlorine to form chlorides of α,α-dichloro acids:

$$R'CCl_2\dot{C}O + Cl_2 \longrightarrow R'CCl_2C\underset{Cl}{\overset{O}{<}} + Cl.$$

At 50-60° there is appreciable breakdown of $CH_3CCl_2\dot{C}O$ radicals:

$$CH_3CCl_2\dot{C}O \longrightarrow CH_3\dot{C}Cl_2 + CO.$$

The breakdown products react with Cl_2 to form 1,1,1-trichloroethane and phosgene:

$$CH_3\dot{C}Cl_2 + Cl_2 \longrightarrow CH_3CCl_3 + Cl; \quad CO + 2Cl \longrightarrow COCl_2.$$

Free dichloroacetic and α,α-dichloropropionic acids are probably formed by hydrolysis of the respective acid chlorides with the water released during binding of hydrochloric acid with the marble introduced at the end of chlorination.

Chlorination of anhydrous α,α-dichloroaldehydes under the specified conditions leads to satisfactory yields of α,α-dichloro-substituted acid chlorides and it can serve as a preparative method when the use of phosphorus pentachloride, sulfuryl chloride and other chlorinating agents is desirable.

Another interesting objective was the study of the chlorination of α-monochloroaldehydes under the same conditions.

The chloroacetaldehyde in our possession contained 5-6% water. Even after keeping for a short period, and sometimes during chlorination of the freshly fractionate substance, stratification was observed due to separation of water as a result of crotonization. Chlorination of such a preparation in ultraviolet light or in presence of acetylcyclohexanesulfonyl peroxide consequently gave only a small yield of dichloroacetyl chloride; the main product that distilled over was dichloroacetic acid. The latter could be formed by hydrolysis of the acid chloride or by oxidation of the aldehyde with hypochlorous acid which is probably formed in presence of water. In the latter event there would also occur substitution of the hydrogen in the α-position to the carbonyl group by chlorine.

EXPERIMENTAL

Dichloroacetaldehyde (b. p. 87.5°) and α,α-dichloropropionaldehyde (b. p. 86°) were obtained by chlorination of ethyl alcohol [5] and n-propyl alcohol [6], respectively, and they were purified by fractionation in a 20-plate column.

Chloroacetaldehyde was obtained by chlorination of acetaldehyde in presence of antimony trichloride [7], also by chlorination of β,β'-dichlorodiethyl ether [8] followed by hydrolysis in presence of calcium carbonate. The preparation obtained by both routes had b. p. 85-87° after three distillations with anhydrous oxalic acid; it contained 42.7% chlorine (equivalent to 30% content of hydrate). 30 g of the aldehyde was placed in a quartz test tube fitted with reflux condenser, thermometer and porous bubbling plate. The tube was irradiated with a PRK-2 quartz mercury lamp at a distance of 9 cm, or 0.15 g acetylcyclohexanesulfonyl peroxide was added. The chlorination period was 10 hours. Heat liberation kept the temperature at 50-60°. The evolved gases were passed through a spiral trap cooled to − 70°. The products of chlorination were kept over marble for 3-4 days and were then fractionated (20 g of chlorinated product was taken). Results of chlorination and fractional distillation are presented in the table.

Results of Chlorination of Chloroaldehydes

Original aldehyde	Dichloroacetaldehyde		α,α-Dichloropropion-aldehyde		Chloroacetaldehyde in admixture with hydrate	
Chlorination condition	in ultra-violet light	in presence of 0.15% peroxide	in ultra-violet light	in presence of 0.15% peroxide	in ultra-violet light	in presence of 0.15% peroxide
Obtained by chlorination of the mixture (in g)	24.5	31.6	24.7	27.3	29.0	25.2
Composition of mixture:						
α,α-dichlorocarboxylic acid chloride	11.5	11.5	12.4	14.4	0.4	1.2
α,α-dichlorocarboxylic acid	3.8	3.5	1.0	4.0	12.6	11.0
1,1,1-trichloroethane	—	—	4	5	—	—

Phosgene was detected in the experiment with α,α-dichloropropionaldehyde: the gaseous products of chlorination were washed free of free chlorine with potassium iodide solution and passed through 3% aniline water; the resulting white precipitate of diphenylurea was evidence of the presence of phosgene.

Dichloroacetyl Chloride

B. p. 107-108°; literature [9]: b. p. 107-108°; identified in the form of dichloroacetamide with m. p. 98° (from benzene); literature [10]: m. p. 98°.

Found %: N 10.74. $C_2H_3ONCl_2$. Calculated %: N 10.93.

α,α-Dichloropropionyl Chloride

B. p. 105-115°; literature data [11]: b. p. 105-115°; identified in the form of α,α-dichloropropionamide with m. p. 116-117° (from benzene); literature data [11]: m. p. 117-118°.

Found %: N 9.81. $C_3H_5ONCl_2$. Calculated %: N 9.85.

Dichloroacetic Acid

B. p. 76-78° (4 mm); literature data [12]: 91-92° (12 mm); identified in the form of the aniline salt with m. p. 123-124° (from alcohol + benzene); no depression of melting point in admixture with the anilide of dichloroacetic acid prepared from chloral [12].

α,α-Dichloropropionic Acid

B. p. 70-73° (3 mm); literature data [13]: b. p. 185-190°; identified in the form of the o-phenylenediamide with m. p. 108-109.5° (from benzene).

Found %: N 7.17. $C_{12}H_{16}O_4N_2Cl_4$. Calculated %: N 7.10.

1,1,1-Trichloroethane.

B. p. 73-74.5° (752 mm); literature data [14]: b. p. 74.9° (758 mm), n_D^{20} 1.4198.

Found %: Cl 79.50. $C_2H_3Cl_3$. Calculated %: Cl 79.70.

SUMMARY

Dichloroacetaldehyde and α,α-dichloropropionaldehyde were chlorinated in ultraviolet light and also in presence of 0.5% acetylcyclohexanesulfonyl peroxide. The products were respectively dichloroacetyl chloride and α,α-dichloropropionyl chloride together with a proportion of the free acids. Under the same conditions the chlorination of chloroacetaldehyde, containing 5-6% water, gives mainly dichloroacetic acid.

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REACTIONS OF PENTAARYLPHOSPHORUS

DETERMINATION OF THE EQUIVALENCE OF THE GROUPS WITH THE AID OF DEUTERIUM

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Investigation of the reactions of pentaarylphosphorus, containing deuterium in one of the phenyl groups, in benzene or chloroform solution showed that detachment of the polar and equatorial phenyl groups takes place with equal facility and involves a radical mechanism [1]. It was of interest to establish whether this equivalence of the polar and equatorial phenyl groups also persisted in ionic breakdown of pentaphenylphosphorus. It is known that the latter substance reacts ionically with hydrogen iodide [2] and acetic acid [1].

Reactions carried out between pentaphenylphosphorus, containing deuterium in one phenyl group, and hydrobromic or acetic acid actually revealed the equivalence of the polar and equatorial phenyl groups even in ionic reactions. As we see from Table 1 (Expts. 1 and 2) the quantity of deuterium in the dinitrobenzene resulting from detachment of phenyl groups is nearly 1/5 of the total quantity of deuterium in the pentaphenylphosphorus.

Expt. No.	Pentaarylphosphorus	Deuterium content (γ) in one group	Solvent	split off from phosphorus				bound to phosphorus			
				calc.		found		calc.		found	
				γ	%	γ	%	γ	%	γ	%
1	$(C_6H_5)_4PC_6D_5$	3828	HBr	765	20	696	18.2	3063	80	3212	84.0
2	$(C_6H_5)_4PC_6D_5$	3828	CH_3COOH	765	20	728	19.0	3063	80	2830	74.1
3	$(C_6H_5)_4PC_6D_4CH_3-p$	6700	HBr	992	20	950	19.2	5708	80	5295	74.1
4	$(C_6H_5)_4PC_6D_4CH_3-p$	6700	$CHCl_3$	992	20	425	8.6	5708	80	6390	89.6
5	$(C_6H_5)_4PC_6D_4CH_3-p$	6700	$CHCl_3$	992	20	540	10.8	5708	80	6400	89.7
6	$(C_6H_5)_4PC_6D_4CH_3-p$	6700	CH_3CH_2OH	895	20	658	14.7	5805	80	6180	85.2

In the light of this observation, it was of interest to establish the effect of replacement of one phenyl group by p-tolyl; would equivalence be observed in the detachment of groups during breakdown of pentaarylphosphorus? Wittig [2] investigated the reaction of tetraphenyltolylphosphorus with hydrobromic acid and found that the reaction products are, apart from benzene and toluene, a mixture of salts (3:1) in the shape of triphenyl-p-tolylphosphonium bromide and tetraphenylphosphonium bromide. The paper does not give, however, the benzene/toluene ratio and the method of determination of the salt ratio.

It seemed to us that the ratio of detached phenyl and tolyl groups could be determined with the help of labeled atoms. We therefore synthesized tetraphenyl-p-tolylphosphorus with deuterium in the ring of the tolyl group, and reacted the compound with hydrobromic acid, chloroform, and alcohol.

The calculated values of deuterium distribution in the products resulting from detachment of radicals and in the radicals remaining in combination with phosphorus, on the assumption of equivalent cleavage of tolyl and phenyl groups, are presented in the table (columns 5 and 9). Comparison with the experimental values (columns 7 and 11) shows that in ionic reactions (with HBr, Expt. 3) the speeds of detachment of tolyl and phenyl groups of tetraphenyl-p-tolylphosphorus are the same. In chloroform (where the reaction goes by a radical mechanism) phenyl radicals are preferentially split off (Expts. 4 and 5). Preferential retention of tolyl groups at the phosphorus atom is also indicated by the fact that the melting point of the prepared iodide of the phosphorus compound is close to the melting point of triphenyl-p-tolylphosphonium iodide [2]. Analysis of the products shows that the reaction is accompanied by detachment of two groups of tetraphenyl-p-tolyl-phosphorus in ethanol. The latter therefore may be said to occupy an intermediate position. In this case, the reaction mechanism is obscure and requires further investigation.

EXPERIMENTAL

The starting substances and the reaction products were analyzed for their deuterium content by flotation of the water resulting from combustion of these compounds. Results were accurate to within 15γ. Allowance was made for the crystallization of the pentaphenylphosphorus and tetraphenyl-p-tolylphosphorus with half a molecule of cyclohexane. Products of detachment of the groups were identified as dinitro compounds. No allowance was made for the isotopic effect of nitration.

Deuterated pentaphenylphosphorus and tetraphenyl-p-tolylphosphorus. $(C_6H_5)_4PC_6D_5$ and $(C_6H_5)_4PC_6D_4CH_3$-p were prepared from tetraphenylphosphonium iodide and deuterated phenyllithium and p-tolyllithium (deuterium in the ring) by Wittig's procedure [2]. Deuterophenyllithium and p-tolyllithium with deuterium in the ring were prepared from deuterated bromobenzene and p-bromotoluene. The latter were obtained by shaking the non-deuterated compounds with deuteriosulfuric acid.

Reactions of $(C_6H_5)_4PC_6D_5$. 1. With hydrobromic acid. 8 g $(C_6H_5)_4PC_6D_6$ and 35 ml HBr (48%) were boiled 30 minutes. The benzene formed in the reaction was distilled off with steam, extracted with carbon tetrachloride and nitrated to m-dinitrobenzene. Yield 2.2 g (75.3%) with m. p. 89°. No depression in a mixed melting test. The residue after steam distillation was treated with KI to give 7.5 g (quantitative yield) of tetraphenylphosphonium iodide with m. p. 330°. A mixture with the iodide obtained by the method of [3] melted without depression.

2. With acetic acid. 8 g $(C_6H_5)_4PC_6D_5$ and 35 ml glacial acetic acid were boiled 30 minutes. 2.0 g m-dinitrobenzene was obtained (68.4%) with m. p. 89°; also 7.6 g (quantitative yield) of tetraphenyl-phosphonium iodide with m. p. 331°.

Reactions of $(C_6H_5)_4PC_6D_4CH_3$-p. 1. With hydrobromic acid. 8 g $(C_6H_5)_4PC_6D_4CH_3$-p and 20 ml HBr (48%) were boiled 30 minutes. The product was worked up as before to give 1.9 g of a mixture of dinitrated benzene and toluene with m. p. 78-80° (a mixture with pure m-dinitrobenzene melted at 82°) and 7.1 g of a mixture of tetraphenylphosphonium and triphenyl-p-tolylphosphonium iodides with m. p. 225°.

2. With chloroform. 10 g $(C_6H_5)_4PC_6D_4CH_3$-p and 20 ml chloroform were stood 2 hours at room temperature. A considerable amount of resins was formed during the reaction. The following substances were isolated: 6 g tetraphenylphosphonium iodide with m. p. 210-215° (no depression of melting point in admixture with the p-tolylphosphonium iodide obtained as in [3]), 2.7 g dinitrated benzene and toluene with m. p. 87° (mixture with pure m-dinitrobenzene melted at 88°), and 4.8 g resins.

3. With ethyl alcohol. 5 g $(C_6H_5)_4PC_6D_4CH_3$-p and 15 ml anhydrous alcohol were boiled 30 minutes. The resulting benzene and toluene were removed by extraction with carbon tetrachloride from the diluted alcohol and nitrated in the extract. There was obtained 2.4 g of dinitro products with m. p. 76°. Traces of diphenyl were eliminated by steam distillation. The residue contained 3.4 g of a mixture of triphenylphosphine oxide and diphenyl-p-tolylphosphine oxide.

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* Original Russian pagination. See C. B. Translation.

REACTIONS OF AROMATIC NITRO COMPOUNDS

VII. THE ABSORPTION SPECTRA OF PRODUCTS OF THE YANOVSKII REACTION

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In one of the preceding communications it was shown that acetone adds on to polynitro compounds in the enol form and that the colored products of the Yanovskii reaction can only be isolated in the free state from inert solvents [1]. Due to the lability of these compounds, their structure and formation mechanism cannot be studied with any degree of thoroughness by the usual methods. The best results are obtained by plotting of the absorption spectra in the visible region. Using this method, Shatenshtein and co-workers [2] established that the Yanovskii reaction has an acid-base mechanism. Newlands and Wild [3] plotted the absorption spectra of a series of products of the Yanovskii reaction.

In the present work, the structure of products of addition of acetone to some polynitro compounds in an alkaline medium was clarified with the help of the absorption spectra.

EXPERIMENTAL

We synthesized all of the starting nitro compounds and purified them by many recrystallizations. Their constants are shown in the table.

Name	Melting point		λ' (mμ)	$\Delta\lambda'$ (mμ)	λ'' (mμ)	$\Delta\lambda''$ (mμ)	λ''' (mμ)
	our data	Literature data [4]					
m-Dinitrobenzene	89.6—89.9°	89.9°	688	—	573	—	—
2,4-Dinitrotoluene	70.5—71.5	71	662	−26	572	— 1	
2,6-Dinitrotoluene	64—65	65—66	—	—	555	−18	
2,6-Dinitro-p-xylene	123.5	123.5	—	—	557	−16	
4,6-Dinitro-m-xylene	91.5—92.5	92—93	646	−42	—	—	
2,4-Dinitro-m-xylene	84.5—85	83—84	—	—	—	—	
2,4-Dinitromesitylene	86	86	—	—	—	—	
Trinitrobenzene (symmetrical)	120—121.5	121—122	570	—	518		462
2,4,6-Trinitrotoluene	80.5—81	82	532	−38	—		462
2,4,6-Trinitro-m-xylene	181.5—182	182	610	+40	—		—

The polynitro compounds were examined as standard solutions in acetone (0.0025 M) and an 0.1 M aqueous potassium hydroxide solution was used.

Aliquot portions of a standard solution of polynitro compound were diluted with acetone to various concentrations, after which a calculated quantity of aqueous potassium hydroxide was added. The mixture was shaken

several times and then examined with the spectrophotometer. The depth of layer in the cell was selected to give the most prominent maximum of absorption. Measurements were made at intervals until the intensity had reached its highest value at the maximum. Use was made of an autorecording SF-2 M spectrophotometer.

Results of measurements are set forth in the table.
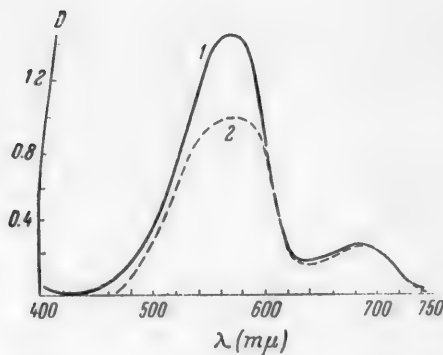Absorption spectra are shown in Figs. 1-3.

Fig. 1. Absorption spectra of acetone solutions of dinitro compounds in presence of alkali;
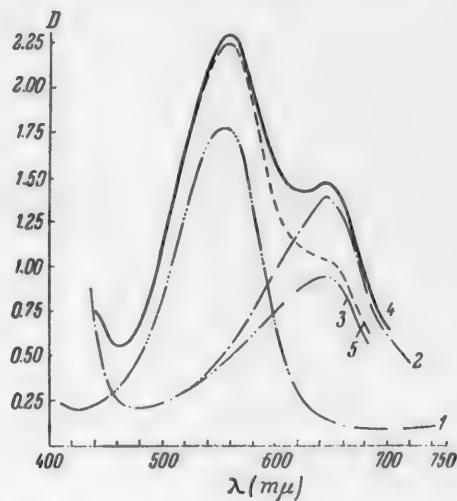1) m-dinitrobenzene; 2) 2,4-dinitrotoluene.

Fig. 2. Absorption spectra of acetone solutions of dinitro compounds in presence of alkali and results of summation of the curves;
1) 2,6-dinitrotoluene; 2 and 3) 4,6-dinitro-m-xylene; 4) summation of 1 and 2;
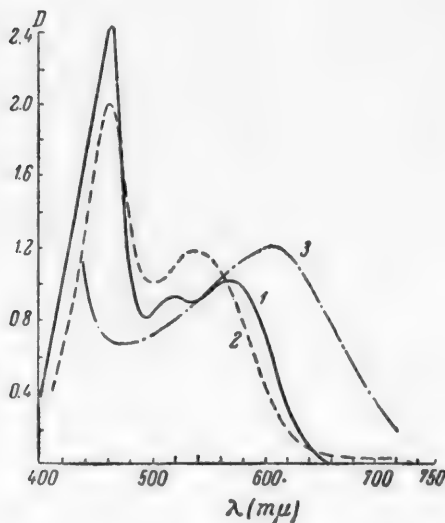5) summation of 1 and 3.

Fig. 3. Absorption spectra of acetone solutions of trinitro compounds in presence of alkali.
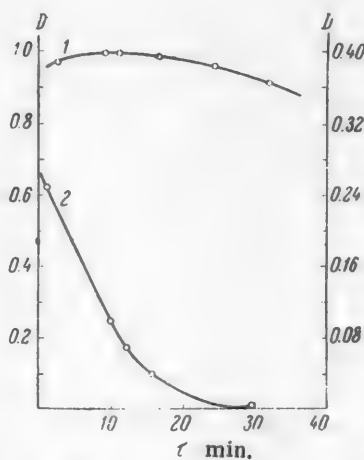1) Symm.-trinitrobenzene; 2) 2,4,6-trinitrotoluene; 3) 2,4,6-trinitro-m-xylene.
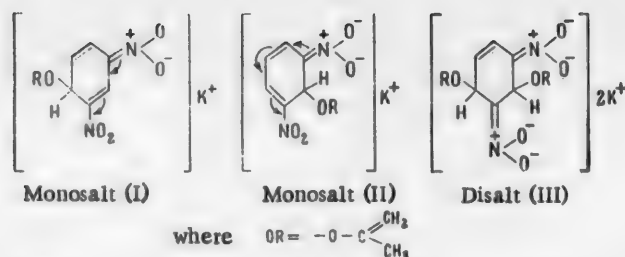

Fig. 4. Change of absorption intensity in the spectrum of complexes of m-dinitrobenzene with time. 1) Short-wave maximum; 2) long-wave maximum.

DISCUSSION OF RESULTS

On the basis of our earlier ideas [1] the formation of the following three products may be assumed in the reaction of m-dinitrobenzene and some of its derivatives with acetone in presence of potassium hydroxide:

Monosalt (I) Monosalt (II) Disalt (III)

$$\text{where}\quad OR = -O-C\begin{smallmatrix} CH_2 \\ \\ CH_3 \end{smallmatrix}$$

The monosalts (I) and (II) are products of equimolar interaction of potassium acetonate with m-dinitrobenzene; addition of two molecules of potassium acetonate to one molecule of m-dinitrobenzene gives the disalt (III).

The color of the monosalts is due to the possibility of transfer of the negative charge of the nitro group along the conjugated chain which in the monosalt (I) consists of three carbon atoms and in the monosalt (II) of five atoms. Monosalt (II) should possess a deeper color and be less stable because the nitro groups are separated by the OR radical which has a larger volume. The disalt (III) will be still less stable because greater steric hindrances must be developed during its formation.

Two maxima were detected in the absorption spectra of the products that we prepared; one of the maxima lies in the 550-580 mμ region (short-wave), the other in the 640-690 mμ region (long-wave). The gradual change in intensity of absorption of these maxima (Fig. 4) clearly indicates that they belong to two different colored complexes. Of the products obtained from dinitrobenzene the most stable in course of time is the compound with λ_{max} 573 mμ; the compound with λ_{max} 688 mμ breaks down rapidly. The spectra thus indicate that only two of the three possible products of the Yanovskii reaction are formed.

In order to establish which of them was formed in the reaction in question and which is associated with a particular maximum, it is necessary to select model molecules which can give one of the addition compounds in question [(I) - (III)] and which consequently give one absorption maximum.

Since 2,4-dinitromesitylene does not form colored products, the methyl group at a carbon atom of the benzene ring hinders the addition of OR residues. The methyl group shields the carbon atom to which it is attached.

In order to exclude the possibility of formation of monosalt (II) and disalt (III), it is necessary to insert a methyl radical between the nitro groups in the dinitro compound. Both of the ortho-positions with respect to the nitro groups in the molecules of 2,6-dinitrotoluene and 2,6-dinitro-p-xylene are equivalent, and the residue can only enter one of them. Consequently, these molecules can give only products of the type of monosalt (I).

(IV) (V)
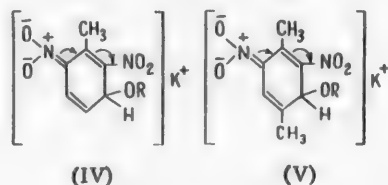
Only one short-wave absorption maximum is indeed detected in the spectra of each of them; in (IV) the maximum is at 555 mμ; in (V) it is at 557 mμ.

(A)
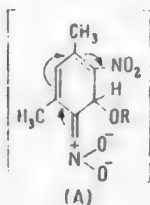
We can therefore assert that the presence of a short-wave maximum in the absorption spectra indicates formation of monosalt (I).

If both of the para-positions in relation to the nitro groups in a molecule of dinitro compound are screened by methyl radicals, then the only possible reaction product will be the monosalt (II). Thus, 4,6-dinitro-m-xylene can form compound (A) with a structure analogous to that of monosalt (II); it gives λ_{max} 646 mμ.

Of the products obtained from dinitro compounds, the monosalt (II) is evidently associated with the long-wave absorption maximum. It should be noted that we did not observe the formation of disalt (III) under these conditions.

A conspicuous feature of the absorption spectra of the majority of dinitro compounds is the considerable shift of the maximum in relation to that of m-dinitrobenzene. These shifts cannot be caused by the joint presence in the solution of two colored complexes. On carrying out a summation of the absorption of the complexes of 2,6-dinitrotoluene and 4,6-dinitro-m-xylene on the basis of the separately plotted absorption curves, (Fig. 2, curve 4), we obtain a shift of 3 mμ for the short-wave maximum and of 1 mμ for the long-wave maximum. When one of the maxima has a low intensity it will appear on the additive curve as an inflection (Fig. 2, curve 5 — summation of curves 1 and 3).

It remains for us to put forward the hypothesis that the main cause of the shifts of the absorption maxima for complexes of polynitro compounds must be the character of the substituent in the benzene ring and the steric hindrance that it creates. The methyl group in the conjugated chain manifests its electron-donating properties. Steric hindrance moreover results from the presence of a methyl group in the vicinity of nitro groups. Both of these factors can contribute to the considerable hypsochromic shifts of these compounds. The shift is 18 mμ for monosalt (I) prepared from 2,6-dinitrotoluene. In monosalt (II) the above-mentioned influence of the methyl groups overlaps with the action of OR groups between the nitro groups (steric hindrance). The result is a considerably greater hypsochromic shift of 42 mμ for the 4,6-dinitro-m-xylene complex. Here the introduction of one methyl group leads to a 26 mμ shift (2,4-dinitrotoluene), and the introduction of the second methyl group is marked by a shift of 16 mμ. If the methyl group is not part of a conjugated chain and does not create steric hindrance, its effect is extremely slight (1 mμ for the short-wave maximum of the 2,4-dinitrotoluene complex, 2 mμ for the 2,6-dinitro-p-xylene complex in relation to the 2,6-dinitrotoluene complex).

Three products of addition of the enol form of acetone are possible for trinitrobenzene and its derivatives. The most deeply colored of these must be the monosalt (VII) since five carbon atoms make up the conjugated chain. The color of the trisalt is caused by the presence of three ionic charges in the molecule.

| (VII) | (VIII) | (IX) |
| Monosalt | Disalt | Trisalt |
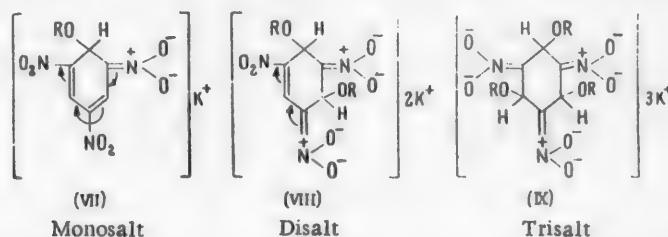
Complexes of trinitro compounds should be very much more stable than dinitro compounds due to their symmetrical structure.

In agreement with the above hypothesis, the absorption spectra of trinitrobenzene contained three maxima of absorption (see table).

Trinitro-m-xylene can form only one complex of the type of monosalt (VII). Our results confirm in this case the existence of one complex with an absorption maximum at 610 mμ, close to the maximum of the trinitrobenzene complexes in the direction of longer waves.

We can accordingly assume that all of the maxima with longer wavelengths in the spectra of derivatives of trinitro compounds are due to the presence of complexes of similar structure. One more confirmation of this hypothesis is the similarity in the pattern of the absorption curves and of the stability time curves of corresponding products. Two maxima appear in the absorption spectra of products of reaction of trinitrotoluene with potassium acetate; these maxima can belong to compounds of the type of the monosalt (VII) and the disalt (VIII). Evidently, the maximum in the longer wave region belongs to monosalt (XI). Consequently, the 462 mμ absorption maximum corresponds to the disalt (XII).
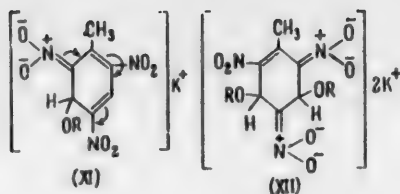
The same maximum (462 mµ) is observed in the spectrum of trinitrobenzene; it corresponds to its disalt. Consequently, it is clear that the third maximum of absorption of products obtained from trinitrobenzene, with a wavelength of 518 mµ, can only belong to the trisalt. As our investigations have shown, this salt is the least stable of all the three trinitrobenzene complexes.

It is necessary to point out that the very large shifts of absorption maxima that we obtained on passing from trinitrobenzene to its substituted derivatives are evidently associated with the electron-donating properties of the methyl groups as well as with the steric hindrance resulting from the presence of such groups.

SUMMARY

1. Absorption spectra were plotted of the products of interaction of polynitro compounds with acetone in an alkaline medium.

2. The structure of products of the Yanovskii reaction was established. It was shown that the color of dinitro compounds subjected to the Yanovskii reaction is due to the formation of monocomplexes. In the case of trinitro compounds, the color is associated with formatiо. of a monosalt and a disalt; only in the case of trinitrobenzene does a trisalt participate in the color.

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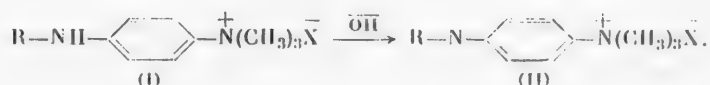[4] Beilst., 5.

Received July 14, 1958

BIPOLAR IONS FORMED BY THE SPLITTING OFF OF A PROTON FROM AN NH-GROUP

XIII. COMPOUNDS OF THE STILBENE SERIES
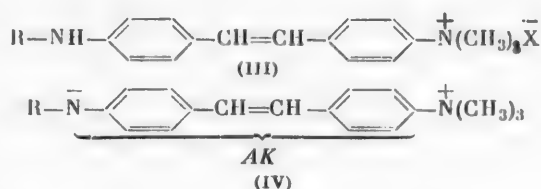
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It has been shown previously [1, 2] that quaternary ammonium salts of structure (I), where R is an electrophilic group, split off a proton from the NH-group under the action of alkali and are converted into bipolar ions of structure (II) *

$$R-NH-\langle\ \rangle-\overset{+}{N}(CH_3)_3\bar{X} \xrightarrow{\overline{OH}} R-N-\langle\ \rangle-\overset{+}{N}(CH_3)_3\bar{X}.$$

<center>(I)   (II)</center>

The formation of such bipolar ions only occurs readily when the R radical is sufficiently electrophilic. If the R is not very electrophilic, the influence of the other electrophilic radical joined to the NH group, i.e., the benzene ring carrying a quaternary ammonium N atom, is insufficient to form a betaine.

In order to check this rule, we synthesized quaternary ammonium salts of structure (III), in which the quaternary N atom and the imino group are joined to a stilbene ring system, i.e., to a more complicated conjugated system than the benzene ring (Table 1), and investigated the conditions for the conversion of these salts into bipolar ions (IV).

$$R-NH-\langle\ \rangle-CH=CH-\langle\ \rangle-\overset{+}{N}(CH_3)_3\bar{X}$$

<center>(III)</center>

$$R-\bar{N}-\langle\ \rangle-CH=CH-\langle\ \rangle-\overset{+}{N}(CH_3)_3$$

<center>AK</center>
<center>(IV)</center>

It might be supposed that, since the radical carrying the quaternary N atom is somewhat more electrophilic, the tendency for conversion into a betaine would be more pronounced in the stilbene series than with benzene derivatives of similar structure.

Our experiments enabled us to show that the replacement of the benzene ring by the stilbene grouping had relatively little influence on the process of betaine formation by these salts. As with quaternary salts containing

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* As the result of redistribution of electron density brought about by the influence of the electrophilic group, the N atom, which has lost a proton, naturally only carries a part of the anionic charge.

a benzene ring of similar structure, salts of the stilbene series (III), containing acetylenic or benzoyl radicals, were not converted into betaines under the action of alkali in aqueous solution. It was not possible, by this means, to convert into bipolar ions the quaternary salts of structure (III), where R was a cinnamyl or benzene-sulfonyl group. Bipolar ions were formed by salts of the stilbene series, containing 2,4-dinitrophenyl, picryl, p-nitrobenzoyl or p-nitrobenzenesulfonyl groups attached to the tertiary N atom, but under the same conditions as with their analogues of structure (II). The effect of the more complicated conjugated system carrying the quaternary N atom was only clearly established in one case — the greater ease of conversion into a bipolar ion of the salt of the stilbene series containing a m-nitrobenzoyl radical attached to the NH group.

TABLE 1

Quaternary Ammonium Salts of Structure

$$\left[RNH-\langle\ \rangle-CH=CH-\langle\ \rangle-\overset{+}{N}(CH_3)_3 \right] C_6H_5S\bar{O}_3$$

R	Melting point	Solvent for crystallization	Formula	Nitrogen content (%)		Color of substance when ground
				found	calc.	
CH₃CO	275—276° (decomp)	Glacial acetic acid	$C_{28}H_{26}O_4N_2S$	6.11	6.19	Colorless
C₆H₅CO	258—260 (decomp)	Acetic acid and alcohol (1:10)	$C_{30}H_{30}O_4N_2S$	5.43	5.44	The same
C₆H₅SO₂	236—238 (decomp)	Alcohol	$C_{29}H_{30}O_5N_2S_2$	5.14	5.12	» »
C₆H₅CH=CHCO	279—280 (decomp)	Acetic acid and alcohol (1:10)	$C_{32}H_{32}O_4N_2S$	5.17	5.18	pale-yellow
n-NO₂C₆H₄CO	270—272 (decomp)	70% acetic acid	$C_{30}H_{29}O_6N_3S$	7.53	7.51	yellow
м-NO₂C₆H₄CO	255—256 (decomp)	Acetic acid and alcohol (1:10)	$C_{31}H_{29}O_6N_3S$	7.52	7.51	The same
n-NO₂C₆H₄SO₂	265—266 (decomp)	Aqueous alcohol	$C_{29}H_{29}O_7N_3S_2$	7.17	7.05	pale-yellow
n-NO₂C₆H₄CH=CHCO	Decomp. without melting at 270—310°	Glacial acetic acid	$C_{32}H_{31}O_6N_3S$	7.20	7.17	Bright yellow
2,4-(NO₂)₂C₆H₃	268—270 (decomp)	70% acetic acid	$C_{29}H_{28}O_7N_4S$	9.67	9.72	Orange
2,4,6-(NO₂)₃C₆H₂	246—247 (decomp)	The same	$C_{29}H_{27}O_9N_5S$	11.23	11.27	Red-orange

The bipolar ions of the stilbene series (Table 2), which we obtained, were brightly colored crystalline substances, soluble in dilute mineral acids and acetic acid, and insoluble in nonpolar solvents. They were somewhat more deeply colored than the bipolar ions of structure (II), obviously because [3] of the lengthening of the π electron chains in the complex electron chromophoric system AK (IV).

EXPERIMENTAL

4-Amino-4'-dimethylaminostilbene was obtained by reduction of 4-nitro-4'-dimethylaminostilbene (m. p. 250-251°) [5] with stannous chloride in glacial acetic acid [6]. The complex of the diamine with the tin salt, precipitated on cooling, was dissolved in 5% hydrochloric acid, and the diamine was liberated by addition of excess of alkali and extracted with benzene on heating and with stirring [7]. The clear benzene solution

was separated when the tin salts had completely dissolved. The diamine deposited in the form of yellow crystalline platelets of m. p. 172-173°, when the solution was cooled. An additional amount of the same material, of m. p. 168-170°, was recovered from the mother liquor by addition of petroleum ether. Yield 72%.

TABLE 2

Bipolar Ions of Structure $R\bar{N}$—⟨⟩—CH=CH—⟨⟩—$\overset{+}{N}(CH_3)_3$

R	Yield (in %)	Melting point	Precipitating agent	Formula	Nitrogen content, %		Color of substance when ground
					found	calc.	
n-NO$_3$C$_6$H$_4$CO	75	216—218°	40% NaOH	C$_{24}$H$_{23}$O$_3$N$_3$	10.85, 10.85	10.47	Red-brown
n-NO$_2$C$_6$H$_4$SO$_2$	94	217—219	NH$_3$, Na$_2$CO$_3$ 2 N KOH	C$_{23}$H$_{23}$O$_4$N$_3$S	9.70, 9.83	9.60	Yellow-orange
м-NO$_2$C$_6$H$_4$CO	73	188—190	2 N KOH	C$_{24}$H$_{23}$O$_3$N$_3$	10.65, 10.34	10.47	Orange
n-NO$_2$C$_6$H$_4$CH=CHCO	69	232—234 (decomp)	Ditto	C$_{26}$H$_{25}$O$_3$N$_3$	9.46, 9.76	9.83	Red-brown
2,4-(NO$_2$)$_2$C$_6$H$_3$	83	197—198	» »	C$_{23}$H$_{22}$O$_4$N$_4$	13.35	13.39	Black
2,4,6-(NO$_2$)$_3$C$_6$H$_2$	84	Decomposes without melting at 250°	NH$_3$	C$_{23}$H$_{21}$O$_6$N$_5$	15.07	15.12	Claret color

TABLE 3

Stilbene Derivatives of Structure RNH—⟨⟩—CH=CH—⟨⟩—$N(CH_3)_2$

R	Melting point	Solvent for crystallization	Formula	Nitrogen content, %		Color of substance when ground
				found	calc.	
CH$_3$CO	238—242°	Acetic acid	C$_{18}$H$_{20}$ON$_2$	9.96	9.99	Colorless
C$_6$H$_5$CO	237—238 (decomp)	Dioxane	C$_{23}$H$_{22}$ON$_2$	8.14	8.18	Yellowish
C$_6$H$_5$SO$_2$	203—204 (decomp)	Alcohol	C$_{22}$H$_{22}$O$_2$N$_2$S	7.43	7.40	Colorless
n-NO$_2$C$_6$H$_4$SO$_2$	242—245 (decomp)	Pyridine	C$_{22}$H$_{21}$O$_4$N$_3$S	9.95	9.92	Red-brown
м-NO$_2$C$_6$H$_4$CO	232—235 (decomp)	Aqueous pyridine	C$_{23}$H$_{21}$O$_3$N$_3$	10.83	10.85	Light-brown
2,4-(NO$_2$)$_2$C$_6$H$_3$	208—210 (decomp)	Pyridine	C$_{22}$H$_{20}$O$_4$N$_4$	13.63	13.85	Dark-brown
2,4,6-(NO$_2$)$_3$C$_6$H$_2$	238—240 (decomp)	The same	C$_{22}$H$_{19}$O$_6$N$_5$	15.50	15.59	Black

N-acyl and N-aryl derivatives of 4-amino-4'-dimethylaminostilbene were obtained by the action of acid chlorides on a solution of the diamine in dry pyridine; the acetyl derivative was obtained by addition of acetic anhydride to a solution of the diamine in 60% acetic acid. The 2,4-dinitrophenyl and picryl derivatives were obtained by interaction of 2,4-dinitrochlorobenzene and picryl chloride with an alcoholic solution of the diamine in the presence of sodium acetate. The properties of the compounds obtained are shown in Table 3. The p-nitrobenzoyl, cinnamyl, and p-nitrocinnamyl derivatives of 4-amino-4'-dimethylaminostilbene, and a number of other derivatives, had been synthesized previously [4, 6].

In order to obtain their quaternary salts, the N-acyl (or N-aryl) derivatives of 4-amino-4'-dimethyl-aminostilbene were fused with the methyl ester of benzenesulfonic acid at 130-140°. The melt was ground up and washed with benzene, and the salt obtained was purified by crystallization.

In order to obtain the bipolar ions of the stilbene series, the initial quarternary salts were dissolved by heating with aqueous alcohol, with addition of a few drops of hydrochloric acid. The hot clear solution was treated with an excess of caustic alkali or (in the case of the picryl derivative) with ammonia. The betaine deposited on cooling was filtered off, washed several times with water and then with alcohol and ether, and finally dried in a vacuum desiccator over phosphorus pentoxide.

The product obtained from methyl p-toluenesulfonate and 4-(m-nitrobenzoylamino)-N-dimethylaniline was similar to the derivative of p-nitrobenzoic acid [2]. It gave white crystals, with a m. p. of 217-218°, from methanol. It was not converted into a betaine by the action of 2 N alkali.

Found %: N 9.09. $C_{23}H_{25}O_{6}N_{3}S$. Calculated %: N 8.91.

SUMMARY

Quaternary ammonium salts of the stilbene series, containing the RNH group (R is acyl or aryl), have been synthesized, starting from 4-amino-4'-dimethylaminostilbene. The properties of these salts (the possibility of their conversion into bipolar ions) agreed with those of the analogous benzene derivatives. Some bipolar ions of the stilbene series were obtained.

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** In Russian.

INTRAMOLECULAR HYDROGEN BONDING AND ULTRAVIOLET ABSORPTION SPECTRA

VI. ABSORPTION SPECTRA OF NITROANILINES

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The peculiarities in the absorption spectra of o-, m- and p-nitroaniline, which have often been considered [1-9], have been explained by the formation of chemical structures [1], differences between the isomers in the stability of intramolecular compounds (without, however, stating their nature) [2], or differences between the isomers in the energy levels between which electron transitions occur [7, 8, 10]. The data on the physical and chemical properties of these substances [11-14] suggests, however, the existence of an intramolecular compound as the result of hydrogen bonding in the case of the ortho isomer.

$$O \leftarrow N = O \cdots H$$
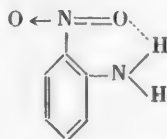
The relation between the different absorption bands and the types of electronic transition should be reflected in the way in which the bands alter with change in solvent type. We have, therefore, measured the absorption spectra of nitrobenzene, aniline (in part) and o-, m- and p-nitroaniline in six different solvents, in which they had not previously been studied, namely: benzene, chloroform, diethyl ether, n-butanol and sulfuric acid, concentrated (98%) and dilute (9.8%). The concentrations of the solutions were varied between 10^{-2} and $5 \cdot 10^{-5}$ M. The results of the measurements with an SP-2 spectrograph are shown in Figs. 1-6. Curves for aniline in diethyl ether and concentrated sulfuric acid were recorded by Scheibe [15].

It can be seen from the figures that the absorption curves of the nitroanilines in neutral solvents differ considerably from those of the monosubstituted benzenes, in that they show: a) a broad band (A) in the long wavelength region between 3400 and 4000 A; b) a small relative shift toward longer wavelength, and a considerable decrease (by a factor of 2-4) in intensity, of the band characteristic of the monosubstituted benzenes in the short-wave region (B); c) a considerable displacement toward longer wavelength of the weak, long wavelength, flexure in the absorption curves of the monosubstituted benzene derivatives (nitrobenzene) (C).

The same relationships between the number and position of the absorption bands are shown by the isomeric nitroanilines, as with other disubstituted benzene derivatives containing one electron donor and one electron acceptor group [16, 17, 9]: the absorption curves of o- and m-nitroaniline consist of two bands of similar intensity (A and B), while the p-nitroaniline curve consists of a single very strong band (A). The absorption curves of o- and m-nitroaniline almost coincide in the short-wave region, but, in the long-wave region, there is a marked difference in position of the maximum of the band (A) and of its long-wave edge. As regards the position of the maximum of the band (A), as follows from the value of $h\nu$, the isomers are arranged in the order: o- < m- < < p- in all solvents except butanol, where the maximum for the para isomer is at a longer wavelength than that
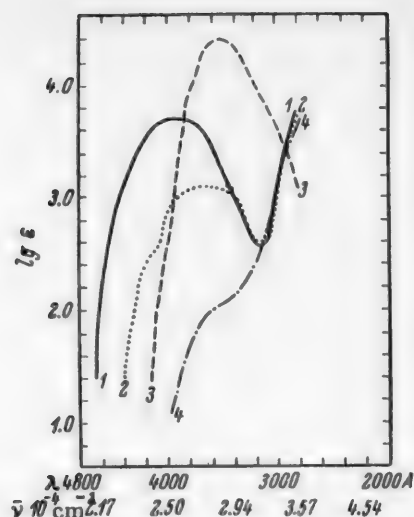
Fig. 1. Absorption spectra in benzene.
1) o-Nitroaniline $(10^{-2} - 10^{-4}$ M);
2) m-nitroaniline $(10^{-2} - 10^{-4}$ M);
3) p-nitroaniline $(10^{-2} - 10^{-4}$ M);
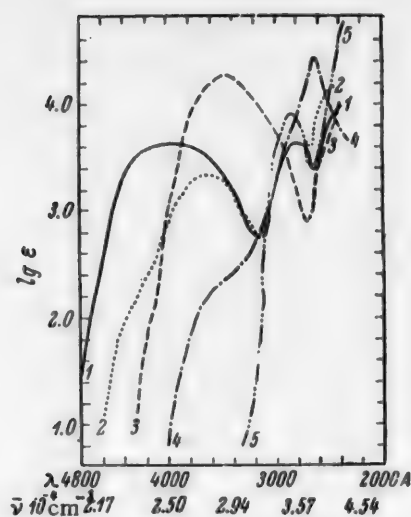4) nitrobenzene $(2 \cdot 10^{-2} - 2 \cdot 10^{-4}$ M).

Fig. 2. Absorption spectra in chloroform.
1) o-Nitroaniline $(10^{-2} - 10^{-4}$ M); 2)
m-nitroaniline $(2 \cdot 10^{-2} - 2 \cdot 10^{-5}$ M); 3)
p-nitroaniline $(2 \cdot 10^{-2} - 4 \cdot 10^{-5}$ M); 4)
nitrobenzene $(2 \cdot 10^{-2} - 2 \cdot 10^{-5}$ M); 5)
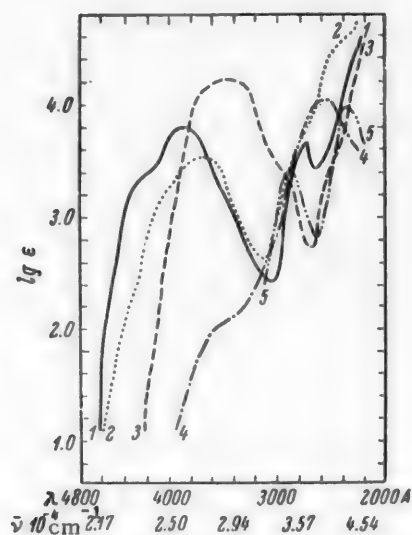aniline $(2 \cdot 10^{-2} - 2 \cdot 10^{-5}$ M).

Fig. 3. Absorption spectra in ether.
1) o-Nitroaniline $(2 \cdot 10^{-2} - 4 \cdot 10^{-5}$ M);
2) m-nitroaniline $(2 \cdot 10^{-2} - 4 \cdot 10^{-5}$ M);
3) p-nitroaniline $(2 \cdot 10^{-2} - 4 \cdot 10^{-5}$ M);
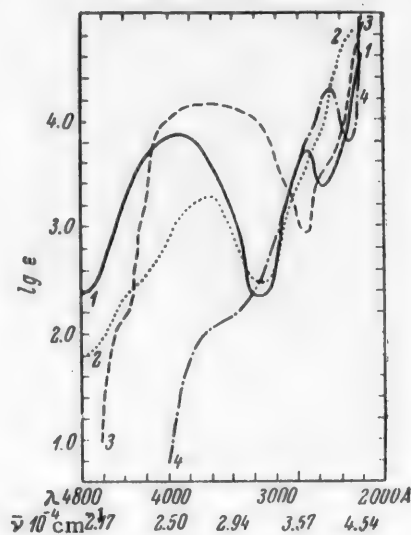4) nitrobenzene $(2 \cdot 10^{-2} - 2 \cdot 10^{-5}$ M);
5) aniline (Scheibe) [15].

Fig. 4. Absorption spectra in butanol.
1) o-Nitroaniline $(10^{-2} - 5 \cdot 10^{-5}$ M);
2) m-nitroaniline $(2 \cdot 10^{-2} - 2 \cdot 10^{-5}$ M);
3) p-nitroaniline $(2 \cdot 10^{-2} - 2 \cdot 10^{-5}$ M);
4) nitrobenzene $(2 \cdot 10^{-2} - 2 \cdot 10^{-5}$ M).

of the meta isomer. The band intensities change in the order: p- > o- > m-; the oscillator strength, as given by the formula $f_e = 4.3 \cdot 10^{-9} \int \epsilon_\nu d\nu$, of the band (A) is almost 6 and 20 times greater for p-nitroaniline than for o- and m-nitroanilines respectively, while the values of $\epsilon_{m-}/\epsilon_{o-}$ and $\epsilon_{p-}/\epsilon_{o-}$ in the different solvents vary between 0.25-0.50 and 2.1-5.0, respectively. The absorption curve of o-nitroaniline also differs from that of m-nitroaniline in that the (A) half band width is greater and approaches that (for example at $\log \epsilon = 3$) of the para isomer.
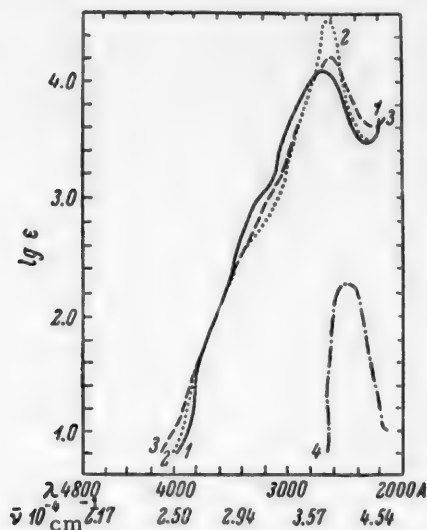

Fig. 5. Absorption spectra in 98% sulfuric acid. 1) o-Nitroaniline $(2 \cdot 10^{-2} - 2 \cdot 10^{-5}$ M); 2) m-nitroaniline $(2 \cdot 10^{-2} - 2 \cdot 10^{-5}$ M); 3) p-nitroaniline $(2 \cdot 10^{-2} - 2 \cdot 10^{-5}$ M); 4) aniline (Scheibe) [15].
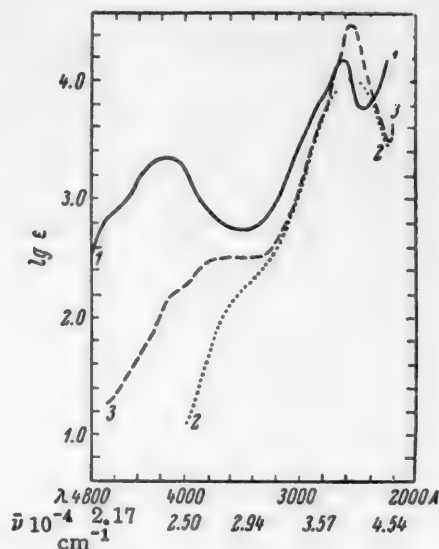
Fig. 6. Absorption spectra in 9.8% sulfuric acid. 1) o-Nitroaniline; 2) m-nitroaniline; 3) p-nitroaniline.

Characteristics of Absorption Curves of Nitroanilines

Nitroaniline	Solvent	Longwave band (A)					$\Delta E = E_{benzene} - E_{solvent}$ (kcal/mole)	$\Delta \lambda = \lambda_{C_6H_4(NH_2)NO_2} - \lambda_{C_6H_5NO_2}$, at $\lg \epsilon = 1.5$ (in Å)
		Maximum, ev	$\Delta E = E_{o-} - E_{m \text{ or } p'}$ (kcal/mole)	$\dfrac{\epsilon_{m \text{ or } p}}{\epsilon_{o-}}$	$\dfrac{B}{2}$ $\lg \epsilon = 3$ (in Å)	f_e		
ortho-	Benzene	3.13	—	—	500	0.09	—	+790
	Chloroform	3.12	—	—	590	0.11	~0	—
	Ether	3.14	—	—	525	0.11	~0	+810
	Butanol	3.05	—	—	530	0.12	+1.97	+1200
meta-	Benzene	3.37	−5.60	0.25	240	0.02	—	+530
	Chloroform	3.35	−5.30	0.50	320	0.04	+0.56	—
	Ether	3.34	−4.60	0.50	385	0.07	+1.13	+710
	Butanol	3.29	−5.52	0.26	225	0.02	+1.97	+1050
para-	Benzene	3.51	−8.76	5.0	560	0.52	—	+280
	Chloroform	3.52	−9.20	4.3	610	0.44	~0	—
	Ether	3.48	−7.82	2.6	585	0.37	+0.84	+420
	Butanol	3.27	−5.04	2.1	740	0.36	+5.64	+710

As is the case with nitrobenzene, the absorption curves of the nitroanilines in chloroform and ether show practically no change from those in benzene. The only difference is that in ether the (A) band maxima of m- and p-nitroanilines show a slight shift toward longer wavelength. In butanol, the (B) band shows hardly any change, but the (A) band, particularly of p-nitroaniline, is considerably displaced toward longer wavelength and is wider. Butanol shows a considerable bathochromic effect on the long wavelength flexure (C).

In concentrated sulfuric acid there is a marked displacement of the absorption curves of all the isomers toward short wavelength, and specific absorption effects are eliminated. The absorption curves of the three nitroanilines practically coincide and resemble that of nitrobenzene in sulfuric acid; compared with the latter, these curves are only slightly displaced toward shorter wavelength. A special feature of the influence of sulfuric acid is the appearance of the band (B) with the para isomer and a considerable increase in its intensity with the other isomers. The latter effect is considerably diminished in dilute sulfuric acid. Thus, in 9.8% sulfuric acid, the absorption curve of o-nitroaniline practically coincides with that in water [2]. Only with m-nitroaniline does the absorption curve remain almost the same in 9.8% acid as in concentrated sulfuric acid. The effect of the latter on the absorption of nitroanilines is clearly associated with salt formation, with the participation of the unshared p-electrons of the nitrogen of the amino group. In this case, judging by the absorption curve in dilute acid, m-nitroaniline gives the most stable salt with sulfuric acid, and o-nitroaniline gives the least stable, as opposed to their behavior with perchloric acid [2].

The band (A) of o-, m-, and p-nitroanilines, like that of similar types of compounds (aminoacetophenones, hydroxyacetophenones, nitrophenols) [6, 16, 17, 8] is clearly associated with the existence in the molecule of one electron donor and another electron acceptor group and with the degree of mobility of their π- and p-electrons. This follows from: a) the absence of this band in the case of disubstituted benzenes containing only electron donor or only electron acceptor functional groups; b) its disappearance, in the case of amino derivatives, in acids as the result of salt formation, and, on the other hand, its abrupt displacement toward longer wavelength in alkaline solution in the case of the corresponding substituted phenols; c) the change in position and oscillator strength of this band on replacement of the functional groups, in conformity with the change in tendency of their π- and p-electrons to share in the conjugation [6, 8, 16]. These features, and also the relatively high oscillator strength and the marked displacement of this band toward longer wavelength on changing from a hydrocarbon to a hydroxyl-containing solvent, indicate that it is due to $N \rightarrow V$ electron transfer, and that absorption is associated with "a transfer of charge" under the influence of the electric field of a light wave [17, 18, 10]. Evidently, the excited state of the molecule for electron transfer, associated with the wave in question, can be represented to a satisfactory approximation by an intramolecular ionization of the structure with considerable separation of charge, of the type*
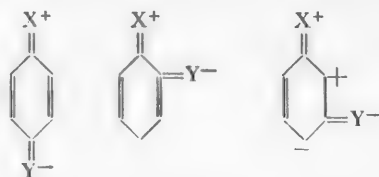
This type of structure, with pairing of the p-electrons of the nitrogen, is also proposed for the metastable state of the p-nitroaniline molecule [19]. This must lead to a stronger bonding with the solvent by the molecule in the excited than in the base state, as the result of dipole forces and hydrogen bonding, of greater strength in the excited state of oxonium compounds (group Y) with molecules of acid, and hence to a displacement of the band (A) toward longer wavelength [20].

The band (B) of the nitroanilines almost coincides in position with that of monosubstituted benzenes (the "second band" [6] or K band [21]). This band is also associated with $N \rightarrow V$ electron transfer [22, 23], leading to displacement of electrons, by optical excitation, to or from the substituent.

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* Here and subsequently + and − only represent the direction of displacement of charge.
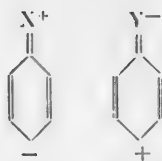
The considerable reduction in ϵ of this band in the case of nitroanilines, as compared with unsubstituted nitrobenzene and aniline, and, on the other hand, the increase in the ϵ of this band in concentrated acid (with elimination of the possibility of $N \rightarrow V$ transitions, associated with the (A) band), and also the opposite natures of the changes in f_e of the (A) and (B) bands with changing mobility of the π-and p-electrons of the substituents [8], suggest the existence in the molecules of the above disubstituted derivatives of different directions of displacement of charge on optical excitation, evidently occurring in some cases in two stages: first, excitation with participation of the π-electrons of the ring system and the π-or p-electrons of only one of the substituents, and secondly with participation of the excited molecule and the electrons of the second substituent group, for example:
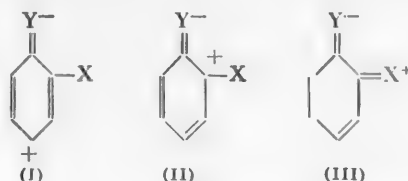
Band (B) is clearly associated with displacement of charge in excitations of types (I) and (II). Its position is also affected by the difference in the interaction between the second substituent and the π-electrons of the ring system in the base and excited states. Evidently, in the case of the para isomer, where the interaction of the group is particularly strong, it is not, as is generally supposed [8], that the band (B) is lacking, but rather that it is displaced in the long-wave direction and, hence, only appears in the form of a bulge or appreciable widening of the short-wave side of the band (A). In the primary excited molecule there is a considerable increase in inter-conjugation of groups (this also becomes possible with the meta isomer), which leads to a displacement of the band (A) toward longer wavelength. The lower probability of secondary excitation with the meta isomer may explain the smaller value of ϵ of its (A) band. This viewpoint also satisfactorily explains the known fact that the absorption curves of polysubstituted, e.g., trisubstituted [16, 24], aromatic compounds can be represented as the result of superimposing those of the corresponding di- and mono-substituted derivatives.

The formation of a hydrogen bond within the molecule of the ortho isomer leads to a cis configuration in the distribution of the corresponding functional groups so that they lie almost in a plane, and, hence, to a considerable displacement of the electron density, even in the base state, in the direction (III). Since, in the excited state, the strength of the intramolecular hydrogen bond increases with intramolecular ionization of the structure, the existence of the latter must lead to a considerable displacement of the band (A) toward longer wavelength and an increase in its intensity. A considerable widening of this band is also possible because the formation of the hydrogen bond strengthens the interaction of the different vibrations of atoms and groups in the molecule [25]. All these features are actually observed in the (A) band of o-nitroaniline. The influence of the intramolecular hydrogen bond on the positions of the other absorption bands is evidently small, and only a comparison of the natures of the changes in these other bands can explain the often repeated view [26] that the hydrogen bond has no effect on the positions of absorption bands in the ultraviolet.

SUMMARY

1. Results are given of measurements of the ultraviolet absorption spectra of nitrobenzene, aniline, and o-, m-, and p-nitroaniline in various solvents.

2. The special features of the spectra of the nitroanilines are similar to those observed with all disubstituted benzenes containing active groups, one of which is an electron donor and the other an electron acceptor.

3. The long-wave (A) band of the nitroanilines is an $N \rightarrow V$ electron transition band, with the electrons of both functional groups participating in the transition.

4. With o-nitroaniline, the existence of intramolecular hydrogen bonding leads to considerable displacement of the (A) band toward longer wavelength and to widening of the band.

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* Original Russian pagination. See C. B. Translation.

ABSORPTION SPECTRA OF DISUBSTITUTED BENZENES WITH SIMILARLY DIRECTING FUNCTIONAL GROUPS

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In order to elucidate the nature of the electron transitions corresponding to the different absorption bands of aromatic compounds in the ultraviolet, it is necessary to consider the special features of absorption by disubstituted benzenes with similarly directing functional groups. There have been numerous investigations on the spectra of such compounds (nitroacetophenone, nitrobenzaldehyde, dinitrobenzene, etc.) [1-8]; but usually only in hexane or ethanol, and not always with all the isomers. Since, in order to determine the nature of the electron transitions, it is necessary to study the changes of the absorption bands in polar, hydroxyl-containing and acid solvents [9-11], we have investigated the spectra of the above type of compound in seven different solvents: nonpolar (hexane, benzene, and dioxane), polar (ether), hydroxyl-containing (n-butanol) and 98 and 9.8% sulfuric acid. The spectra, in these solvents, of nitrobenzene and of its o-, m- and p-acetyl derivatives are shown below. The spectra of the latter are of interest in connection with the existence in the meta isomer of an indirect (through the ortho hydrogen atom) steric effect, which is clearly indicated by an abrupt fall in absorption intensity [8].

o-Nitroacetophenone was obtained from o-nitrobenzoic acid [12], and purified by distillation under reduced pressure at 137-138° (5 mm); [7, 12]: 159° (16 mm), 119° (4 mm) and 112.5-113.5° (2 mm). p-Nitroacetophenone was obtained in the same way from p-nitrobenzoic acid, and purified by crystallization from alcohol; m. p. 80°; [7, 12]: 79°, 80-81°. m-Nitroacetophenone was obtained by nitration of acetophenone [13] and purified by crystallization from aqueous alcohol; m. p. 80°; [7, 13]: 76-78°, 78°. The absorption curves of nitrobenzene and of the acetophenones are shown in Figs. 1-11; the curves for nitrobenzene and acetophenone in hexane and for acetophenone in concentrated sulfuric acid are taken from the published data [14-16].

The absorption curves of o-, m-, and p-nitroacetophenones in hexane (Fig. 1) differ from those of disubstituted benzene derivatives with one electron donor group and a different electron acceptor group, in the position and number of the bands, first in their similarity to each other, and second in their resemblance to those of the corresponding monosubstituted derivatives. Each curve consists of a long-wave flexure at 3100 to 3300 A (ϵ 160-350) (for nitrobenzene in hexane at 3300 A with ϵ 140), a second flexure (with the ortho and meta isomers) at 2810-2840 A (ϵ 1200) (with nitrobenzene and acetophenone the corresponding flexure and maximum are at 2800 and 2865 A respectively with ϵ 1000) [17], and a third maximum (or flexure with the meta isomer) between 2400 and 2550 A (ϵ 12,000-25,000) (with nitrobenzene and acetophenone this maximum is at 2520 and 2370 A with ϵ 10,000 and 13,000, respectively) (band B). Compared with the absorption curve of nitrobenzene, that of p-nitroacetophenone shows a displacement of the whole curve toward longer wavelength, with a considerable increase in oscillator strength (by a factor of about 3) and a widening of the band B; with o-nitroacetophenone the position of maximum of band B, its width and oscillator strength (f_e) are almost the same as for nitrobenzene; only over the range between log ϵ = 1.5 -3.1 is the absorption curve somewhat displaced toward longer wavelength compared with that of nitrobenzene. The absorption curve of m-nitroacetophenone coincides almost exactly with that of nitrobenzene. All these relationships are preserved in such nonpolar solvents as benzene and dioxane (Figs. 2-4). As with nitrobenzene, there is some displacement, in these solvents as compared with hexane, toward longer wavelength, of the curve above the long-wave flexure (above
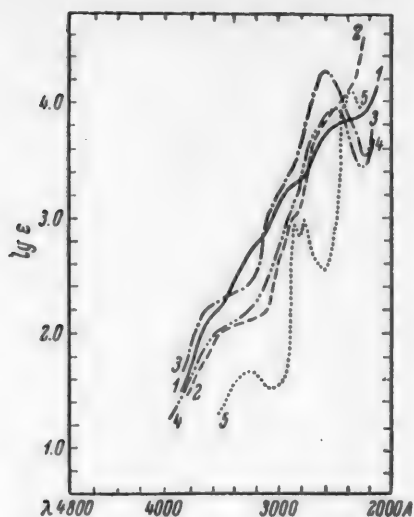
Fig. 1. Absorption spectra in hexane.
1) o-Nitroacetophenone ($5 \cdot 10^{-3}$ to
$5 \cdot 10^{-5}$ M); 2) m-Nitroacetophenone
($5 \cdot 10^{-3} - 5 \cdot 10^{-5}$ M); 3) p-nitro-
acetophenone ($25 \cdot 10^{-4} - 25 \cdot 10^{-6}$ M);
4) nitrobenzene according to Dede
and Rosenberg [14]; 5) acetophenone
according to Valyashko and Rozum [15].

Fig. 2. Absorption spectra of o-nitro-
acetophenone in nonpolar solvents.
1) In benzene ($1 \cdot 10^{-2} - 1 \cdot 10^{-4}$ M);
2) in hexane ($5 \cdot 10^{-3} - 5 \cdot 10^{-5}$ M);
3) in dioxane ($2 \cdot 10^{-2} - 4 \cdot 10^{-5}$ M).

Fig. 3. Absorption spectra of m-nitro-
acetophenone in nonpolar solvents.
1) In hexane ($5 \cdot 10^{-3} - 5 \cdot 10^{-5}$ M);
2) in dioxane ($2 \cdot 10^{-2} - 4 \cdot 10^{-5}$ M);
3) in benzene ($1 \cdot 10^{-2} - 2 \cdot 10^{-4}$ M).
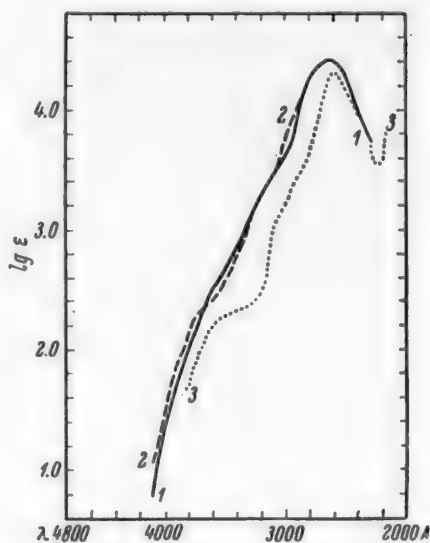
Fig. 4. Absorption spectra of p-nitroaceto-
phenone in nonpolar solvents.   1) In
dioxane ($2 \cdot 10^{-2} - 4 \cdot 10^{-5}$ M); 2) in
benzene ($1 \cdot 10^{-2} - 1 \cdot 10^{-4}$ M); 3) in
hexane ($2.5 \cdot 10^{-3} - 2.5 \cdot 10^{-5}$ M).
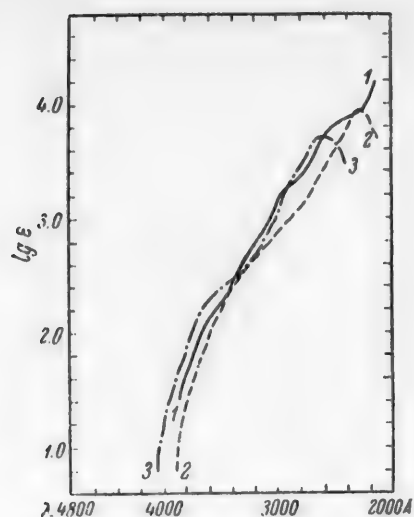
Fig. 5. Absorption spectra of o-nitro-
acetophenone in polar solvents. 1)
In hexane $(5 \cdot 10^{-3} - 5 \cdot 10^{-5}$ M); 2)
in ether $(2 \cdot 10^{-2} - 2 \cdot 10^{-4}$ M); 3) in
n-butanol $(2 \cdot 10^{-2} - 2 \cdot 10^{-4}$ M).
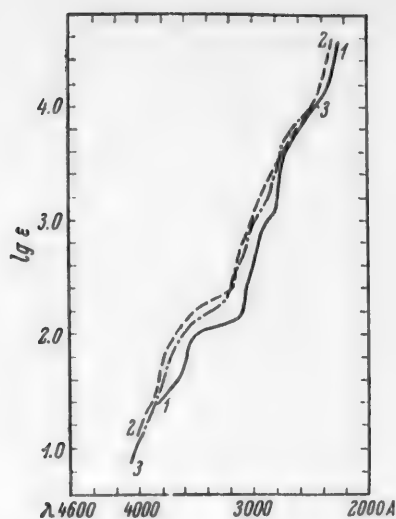
Fig. 6. Absorption spectra of m-nitro-
acetophenone in polar solvents. 1) In
hexane $(5 \cdot 10^{-3} - 5 \cdot 10^{-5}$ M); 2) in
ether $(1 \cdot 10^{-2} - 2.5 \cdot 10^{-5}$ M); 3) in
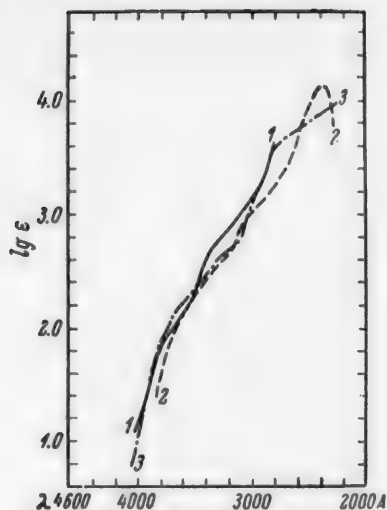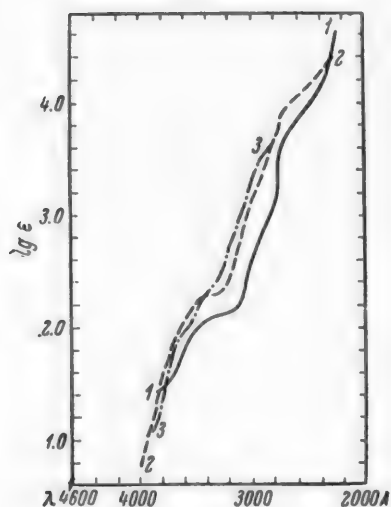n-butanol $(2 \cdot 10^{-2} - 2 \cdot 10^{-5}$ M).
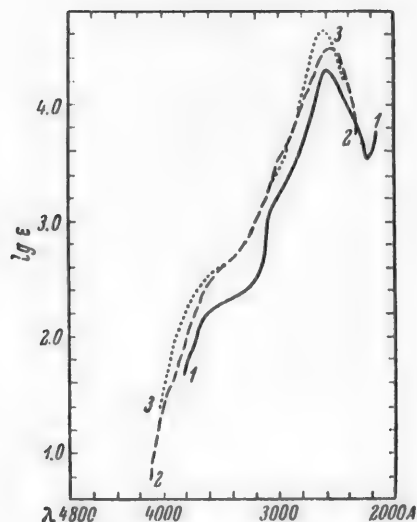
Fig. 7. Absorption spectra of p-nitro-
acetophenone in polar solvents. 1)
In hexane $(25 \cdot 10^{-4} - 25 \cdot 10^{-6}$ M);
2) in ether $(2 \cdot 10^{-2} - 2 \cdot 10^{-5}$ M);
3) in n-butanol $(5 \cdot 10^{-3} - 2 \cdot 10^{-5}$ M).
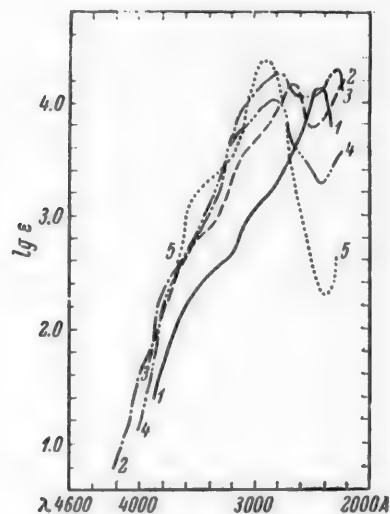
Fig. 8. Absorption spectra in sulfuric acid.
1) o-Nitroacetophenone in hexane $(5 \cdot 10^{-3}$
to $5 \cdot 10^{-4}$ M); 2) in 98% H_2SO_4 $(2 \cdot 10^{-2}$ to
$2 \cdot 10^{-5}$ M); 3) in 9.8% H_2SO_4 $(2.5 \cdot 10^{-3}$ to
$2.5 \cdot 10^{-5}$ M); 4) nitrobenzene in 98% H_2SO_4
$(2 \cdot 10^{-2} - 2 \cdot 10^{-4}$ M); 5) acetophenone in
99% H_2SO_4 (according to Flexer [16]).

log ϵ = 2.0-2.5). Below this flexure, the curve of nitrobenzene is almost unaltered, that of p-nitroacetophenone is slightly displaced toward shorter wavelength, while those of the ortho and meta isomers are slightly displaced toward longer wavelength.
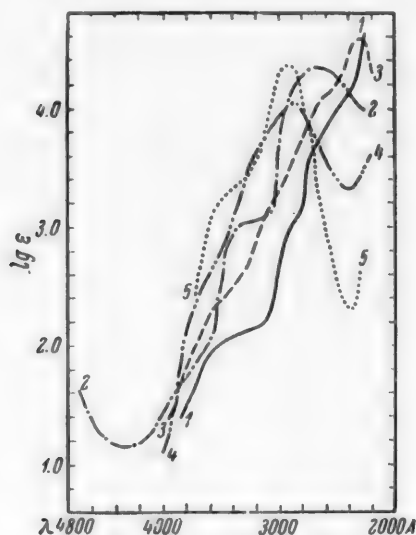
Fig. 9. Absorption spectra in sulfuric acid. 1) m-Nitroacetophenone in hexane $(5 \cdot 10^{-3} - 5 \cdot 10^{-5}$ M)₤ 2) in 98% sulfuric acid $(2 \cdot 10^{-2} - 2 \cdot 10^{-5}$ M)₤ 3) in 9.8% sulfuric acid $(5 \cdot 10^{-3}$ to $5 \cdot 10^{-5}$ M)₤ 4) nitrobenzene in 98% sulfuric acid $(2 \cdot 10^{-2} - 2 \cdot 10^{-4}$ M)₤ 5) acetophenone in 99% sulfuric acid (according to Flexer [16]).
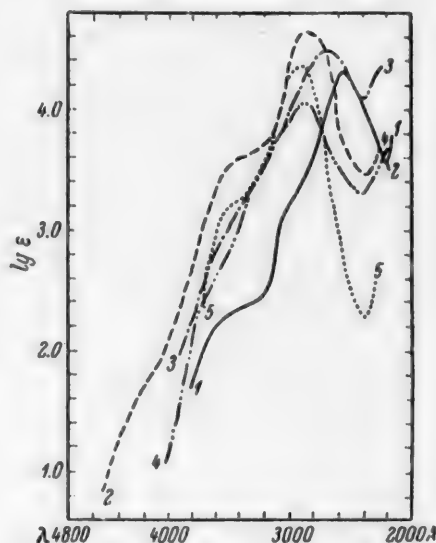
Fig. 10. Absorption spectra in sulfuric acid. 1) p-Nitroacetophenone in hexane $(25 \cdot 10^{-4} - 25 \cdot 10^{-6}$ M)₤ 2) in 98% H_2SO_4 $(2 \cdot 10^{-2} - 2 \cdot 10^{-5}$ M)₤ 3) in 9.8% H_2SO_4 $(1.25 \cdot 10^{-3}$ to $1.25 \cdot 10^{-5}$ M)₤ 4) nitrobenzene in 98% H_2SO_4 $(2 \cdot 10^{-2} - 2 \cdot 10^{-4}$ M)₤ 5) acetophenone in 99% H_2SO_4 (according to Flexer [16]).

Characteristics of the Absorption of the Nitroacetophenones in the Region of the Band B

| Compound | Band B in hexane | | | $\dfrac{\epsilon_{nitroacetophenone}}{\epsilon_{nitrobenzene}}$ | $E_{hexane} - E_{butanol}$, kcal/mole | $\Delta E = E_{hexane} - E_{conc. H_2SO_4}$, kcal/mole |
	E maximum in ev	I_o	half width B/2, at log ϵ = 3.5, in A			
Nitrobenzene	4.87	0.22	230	—	+7.6	+16.9
Acetophenone	5.16	0.16	—	—	+2.9	+21.0
					(in ethanol)	
Nitroaceto-phenones						
o-	5.10	~0.24	~190	~0.75	~+7.4	~+15.4
m-	~4.94	—	—	~0.95	~+4.6	~+11.0
p-	4.74	0.65	320	2.5	+2.9	+11.5

With nitrobenzene in ether and butanol (Fig. 11), the curves are practically identical in both solvents above log ϵ 1.8-2.0, with a relatively small displacement toward longer wavelength; the edge of the long-wave flexure is not affected by this change. The same is observed with the nitroacetophenones in these solvents (Figs. 5-7) as compared with hexane. With the m- and o-nitroacetophenones, the edge of the long-wave flexure also undergoes a slight shift toward longer wavelength. In butanol, the maximum of the band B of the nitro-acetophenones shows a considerable shift toward longer wavelength (215 and 70 A for the ortho and para isomers respectively). With the ortho isomer in this solvent, there is also a considerable reduction in absorption intensity in the region of the B band (almost by a factor of 2.5).

In concentrated sulfuric acid, the nitroacetophenones (Figs. 8-10), like nitrobenzene and acetophenone, show considerable bathochromic and some hyperchromic effects. The change in intensity of the band B ($\Delta E = E_{hexane} - E_{98\% H_2SO_4}$), particularly for o-nitroacetophenone, is very close to that of nitrobenzene. The absorption curve of o-nitroacetophenone in concentrated sulfuric acid almost coincides with that of unsubstituted nitrobenzene in this medium; the m-nitroacetophenone curve shows some shift (particularly relative to that of acetophenone in concentrated sulfuric acid) toward shorter wavelength; the p-nitroacetophenone absorption curve differs from those of the ortho and meta isomers in that there is a considerable shift to longer wavelength, as compared with those of nitrobenzene and acetophenone. In this, the absorption curve of the para isomer is closer to that of aceto-phenone in concentrated sulfuric acid than to that of nitrobenzene. Dilution with water, to an acid concentration of 9.8%, largely eliminates the above mentioned effect with the latter. Here again, as with butanol and the other solvents, the long-wave flexure of para-nitroacetophenone in 9.8% acid almost coincides with its position in hexane, and the curve above log ϵ = 2.3 is somewhat displaced toward longer wavelength; with o- and m-nitroaceto-phenones in this medium, the entire curves, including the long-wave flexure, are displaced toward longer wavelength compared with those in hexane, and, for all the isomers, the displacement considerably exceeds that in neutral solvents.

Fig. 11. Nitrobenzene in different solvents.
1) In hexane (according to Dede [14]);
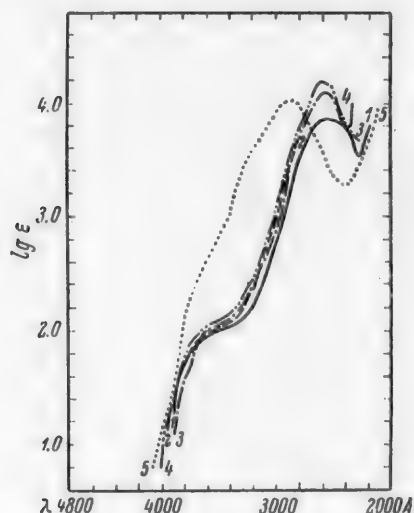2) in benzene ($2 \cdot 10^{-2} - 2 \cdot 10^{-4}$ M); 3) in ether ($2 \cdot 10^{-2} - 2 \cdot 10^{-5}$ M); 4) in n-butanol ($2 \cdot 10^{-2} - 2 \cdot 10^{-5}$ M); 5) in 98% H_2SO_4 ($2 \cdot 10^{-2} - 2 \cdot 10^{-4}$ M).

The resemblance between the absorption curves of the nitroacetophenones and those of the corresponding monosubstituted benzenes (particularly nitrobenzene) is in accordance with the view that, in compounds with similarly directing active functional groups the simultaneous participation of both groups in conjugation with π-electrons of the ring is inconsiderable or, in general, does not occur. When a quantum of light is absorbed by such a type of compound, as by a monosubstituted benzene, only one of the functional groups participates in the transfer of charge of the π-electrons, i.e., the transition to the excited state only leads to the formation of the same intramolecular ionized structure as with monosubstituted benzenes [18-20]:
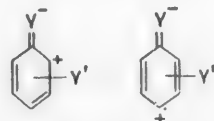
Evidently, the compounds we are considering differ from disubstituted benzenes with functional groups of opposite character, such as the nitroanilines [20], where, in addition to the bands characteristic of monosubstituted benzenes, there is a strong band A in the longer wavelength part of the spectrum, which is associated with participation of the electrons of both substituents in the transfer of charge on excitation. The interaction of the functional groups in the nitroacetophenones only produces some displacement toward longer wavelength of the absorption curves of the ortho, and particularly of the para isomer, as compared with that of nitrobenzene. This interaction amounts to a mutual weakening of the degree of conjugation of each of the functional groups with

the π-electrons of the ring system and of its inductive effect, as also follows from data on the vibration frequency of the carbonyl group of the nitroacetophenones [7]. The displacement of the absorption to longer wavelength, as compared with unsubstituted nitrobenzene, suggests that this weakening effect of the second group is less in the excited than in the base state.

The low long-wave intensity (ϵ 10-100) band (or flexure) of monosubstituted benzenes is associated with $p \to \pi^*$ electron transition (from a nonbonding to a bonding orbital) within the whole functional group [9]. This type of band is considered characteristic of a low oscillator strength, and shifts to shorter wavelength in hydroxyl-containing solvents or acids [9, 11]. This type of low intensity band (or flexure) does not occur with nitrobenzene or its acetyl derivatives, and, as regards the other special characteristic of $p \to \pi^*$ electron transition bands, we find that, in butanol and concentrated sulfuric acid, not only is there no shift to shorter wavelength, but in many cases there is a slight shift to longer wavelength, as compared with the position in hexane. It is possible that, for functional groups with π-and some paired p-electrons (e.g., nitro and carbonyl groups), where only the π-electrons participate in conjugation, intermolecular interaction with participation of p-electrons (formation of hydrogen bonds or oxonium compounds) may lead to some displacement toward longer wavelength of absorption bands caused by $p \to \pi^*$ electron transitions.

Some displacement toward shorter wavelength of the B band maximum and the abrupt decrease in its intensity in o-nitroacetophenone, as compared with p-nitroacetophenone (in alcohol solution), suggests the existence in the former of a considerable steric effect, producing a greater increase in the energy level of the molecule in the excited than in the base state [6, 7, 21]. To a less extent, a similar "indirect" steric effect has also been assumed [8] to explain the reduction in the value of ϵ for m-nitroacetophenone, as compared with the para isomer. Our data for hexane solutions confirms the existence of a considerable steric effect with o-nitroacetophenone, the maximum of whose B band shows a shift, compared to that of p-nitroacetophenone, of 115 A toward shorter wavelength and a decrease of intensity by a factor of nearly 2.5. Evidently, the steric effect with the ortho isomer compensates for the bathochromic and hyperchromic effects of the group interaction observed in the compounds under consideration (with the para isomer), so that the position of the band B remains almost the same as with unsubstituted acetophenone. In this case, the displacement of the B band of m-, as compared with p-nitroacetophenone, is not due to an "indirect" steric effect, but to the absence in the former of any considerable group interaction and hence to its absorption being almost unchanged from that of the original monosubstituted benzene.

SUMMARY

1. Results are given of measurements of the ultraviolet absorption spectra of o-, m-, and p-nitroacetophenones and nitrobenzene in seven different solvents.

2. The absorption curves of the nitroacetophenones are similar, both in number and position of bands and in the way they change with the nature of the solvent, both to each other and to the absorption curves of monosubstituted benzenes (mainly nitrobenzene).

3. The features of the spectra of this type of compound are associated with the difficulty of charge transfer in the excited molecule, with participation of the electrons of both substituents.

4. The existence of a steric effect is only confirmed in the case of o-nitroacetophenone.

5. The absorption band associated with $p \to \pi^*$ transitions, in the case of groups with π and some paired p-electrons, is not subjected to a hypsochromic shift in hydroxyl-containing solvents and acids.

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[*]See C. B. Translation.

THE SPECTRA AND HALOCHROMISM OF TETRAPHENYLMETHANE AND
OF ITS HYDROXY AND METHOXY DERIVATIVES

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The appearance of a color, when certain tetrasubstituted aromatic derivatives of methane are dissolved in acids, has often been noted. A. Bistrzicki and his co-workers [1-3] dissolved triphenylacetic acid and a number of its derivatives in concentrated sulfuric acid, and obtained color changes from orange to dark red. D. Boyd and D. Hardy [4] obtained orange solutions of 4 hydroxy- and 4-methoxy tetraphenylmethane in concentrated sulfuric acid. A. N. Nesmeyanov and his co-workers [5, 6] showed that a number of compounds containing hexamethyltriaminotriphenylmethyl groups reacted with acetic and other carboxylic acids to form violet solutions.

The formation of colored solutions in acetic acid was also noted by O. F. Ginzburg and V. P. Terushkin [7] for dimethylamino derivatives of triphenyl-(1-phenyl-3-methylpyrazolone-5-yl-4)-methane, and by O. F. Ginzburg [8] for 1-phenyl-3-methyl-4-(9'-phenyl-10'-methyl-9',10'-dihydroacridine-9')-pyrazolone-5.

In all the above cases, when the organic substance reacted with acid, its molecule was split at a carbon-carbon bond.

We showed, in our previous publications [9, 10] on the absorption spectra of tetraphenylmethane and of its hydroxy and methoxy derivatives, that the appearance of a color in acid solutions of these compounds was associated with the formation of carbonium ions.

Figures 1-5 show the absorption curves of solutions of tetraphenylmethane and of its hydroxy and methoxy derivatives in neutral and in acid solvents. With neutral solutions of all these compounds the absorption of light was characterized by curves located in the medium and short ultraviolet regions with absorption bands of the phenol type [11-13]. The absorption of light by acid solutions differed considerably from that by neutral solutions. In the curves for all the compounds, part of the visible spectrum was occupied by a new wide region of selective absorption, with one band in the case of tetraphenylmethane and its hydroxy and methoxy derivatives (in acetic-sulfuric acid solutions this band was split by a small saddle), and two very well defined bands in the case of dihydroxy- and dimethoxytetraphenylmethanes.

Since the color produced by interaction of these compounds with acids vanished abruptly on dilution with water or alcohol, and the bands in the visible part of the spectrum disappeared, it is probable that the source of color was halochromic in nature.

It is now well known that the formation of color by the phenomenon of halochromism is associated with the formation of carbonium ions, for example by the acid-base interaction [14, 15]

$$(C_6H_5)_3COH + 2H_2SO_4 \rightleftarrows [(C_6H_5)_3C]^+ + 2HSO_4^- + H_3O^+,$$

either by the addition of a proton to a double bond [16, 17]

$$(C_6H_5)_2C{=}CH_2 + H^+ \rightarrow |(C_6H_5)_2C{-}CH_3|^+,$$
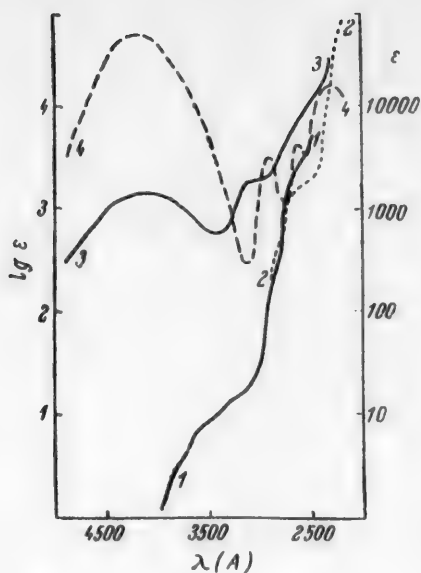
Fig. 1. Tetraphenylmethane.
1) In $CHCl_3$; 2) in C_2H_5OH, 3) in concentrated $H_2SO_4 + 20\%$ $(CH_3CO)_2O$; 4) triphenylcarbinol in concentrated H_2SO_4.
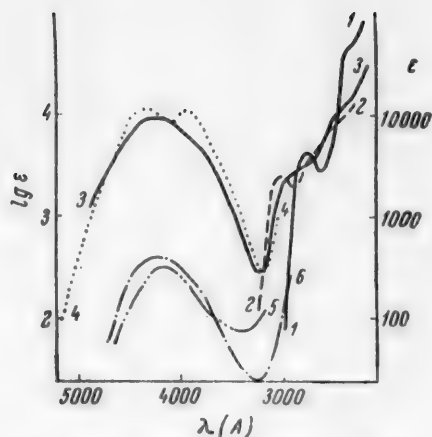
Fig. 2. 4-Hydroxytetraphenylmethane.
1) In C_2H_5OH; 2) in $C_2H_5OH + NaOC_2H_5$; 3) in concentrated H_2SO_4; 4) in 30% H_2SO_4 in CH_3COOH; 5) in 44% H_3PO_4 in $(CH_3CO)_2O$; 6) in 90% CCl_3COOH.
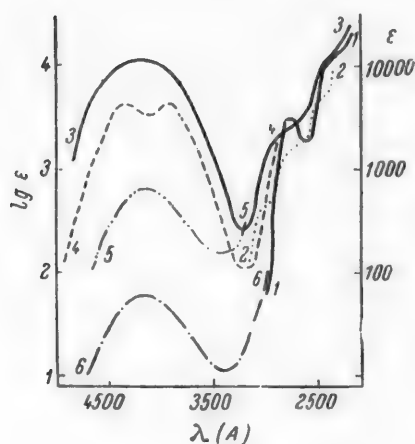
Fig. 3. 4-Methoxytetraphenylmethane.
1) In C_2H_5OH; 2) in $C_2H_5OH + NaOC_2H_5$; 3) in concentrated H_2SO_4; 4) in 30% H_2SO_4 in CH_3COOH; 5) in 44% H_3PO_4 in $(CH_3CO)_2O$; 6) in 90% CCl_3COOH.
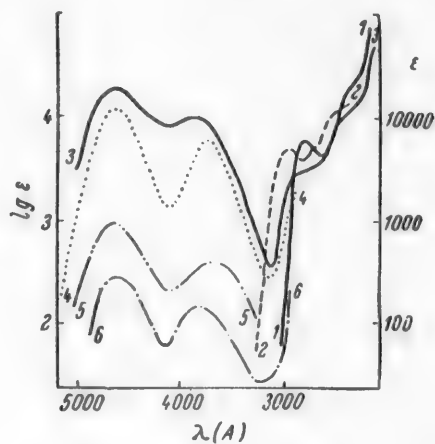
Fig. 4. 4,4'-Dihydroxytetraphenylmethane.
1) In C_2H_5OH; 2) in $C_2H_5OH + NaOC_2H_5$; 3) in concentrated H_2SO_4; 4) in 30% H_2SO_4 in CH_3COOH; 5) in 44% H_3PO_4 in CH_3COOH; 6) in 90% CCl_3COOH.

or to an aromatic ring [18]

$$C_6H_6 + H^+ \longrightarrow C_6H_7^+.$$
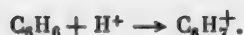
But, taking the above facts [1-8] into consideration, it seems more probable that the formation of carbonium ions by the interaction of triphenylmethane, or of its hydroxy or methoxy derivatives, with acid, occurred as the result of splitting of the molecule at a carbon-carbon bond.

Although tetraphenylmethane is a very stable compound, and can be distilled without decomposition at atmospheric pressure at 431°, as was shown by P. P. Shorygin and I. V. Machinskaya [19], yet it is easily split up in ether solution under the influence of a liquid alloy of potassium and sodium.

The splitting of tetraphenylmethane by sulfuric acid should give triphenylcarbonium sulfate, so that, for comparison, we measured the absorption curve of a sulfuric acid solution of triphenylcarbinol, which is known [14, 15] to give the above salt. Comparison of the absorption curves of acid solutions of tetraphenylmethane and triphenylcarbinol (Fig. 1, curves 3 and 4) shows the common character of the absorption in the long-wave region of the spectrum. We concluded from this that the new absorption band of tetraphenylmethane must be due to the formation of a triphenylcarbonium cation

$$(C_6H_5)_3C-C_6H_5 \xrightarrow{H_2SO_4} [(C_6H_5)_3C]^+,$$

produced as the result of fission by concentrated sulfuric acid.

Fission of the molecule of 4-hydroxytetraphenyl methane is possible in two ways:

$$(C_6H_5)_3C \dashv C_6H_4OH \text{ and } \begin{matrix} HOC_6H_4 \\ (C_6H_5)_2 \end{matrix}\!\!> C \dashv C_6H_5,$$
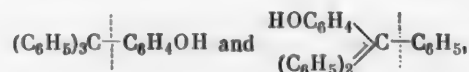
giving cations of different structures. To investigate the possibility of fission and where it occurred, it was necessary to compare the absorption spectra of acid solutions with those of solutions of such compounds for which the formation of the corresponding ions was more probable.

Starting from these considerations, we measured the absorption spectra of acid solutions of triphenylcarbinol and 4-hydroxytriphenylcarbinol. Comparison of the spectra showed that 4-hydroxytriphenylmethane (Fig. 2) gave the same type of absorption as triphenylcarbinol (Fig. 6). We therefore presumed that it reacted with acids similarly to triphenyl carbinol

$$(C_6H_5)_3C-C_6H_4OH + HX \longrightarrow [(C_6H_5)_3C]^+X^- + C_6H_5OH$$

to give a carbonium salt whose cation was responsible for the color of the solution.

The occurrence of this process was confirmed by the isolation of phenol in 10% yield when a solution of the substance in trichloroacetic acid was boiled. Triphenylcarbinol [4] in 15% yield was obtained from the sulfuric acid solution diluted with water. Its formation under these conditions was only possible as the result of hydrolysis of such a carbonium salt

$$[(C_6H_5)_3C]^+HSO_4^- + H_2O \longrightarrow (C_6H_5)_3COH + H_2SO_4.$$

There was no significant difference between the spectra of acid solutions of hydroxy- and methoxy-tetraphenylmethane (Figs. 2 and 3), so it is considered that the color of solutions of the latter compound was due to a similar process.

$$(C_6H_5)_3C-C_6H_4OCH_3 + HX \longrightarrow [(C_6H_5)_3C]^+X^- + C_6H_5OCH_3$$

Comparison of the absorption curves of acid solutions of 4,4'-dihydroxytetraphenylmethane, triphenyl carbinol and 4-hydroxytriphenylcarbinol (Figs. and 6) showed the common character of the absorptions by

the first and third substances. This enabled us to conclude that the color with the dihydroxy derivative of tetraphenylmethane was associated with the following salt formation reaction

$$\begin{array}{c} HOC_6H_4 \\ (C_6H_5)_2 \end{array}\!\!\!\!\searrow\!\!C-C_6H_4OH + HX \longrightarrow \left[\begin{array}{c} HOC_6H_4 \\ (C_6H_5)_2 \end{array}\!\!\!\!\searrow\!\!C\right]^+ X^- + C_6H_5OH.$$
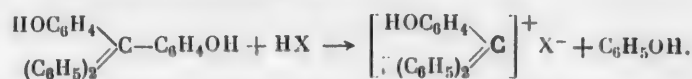
Splitting of the molecule of 4,4'-dihydroxytetraphenylmethane was confirmed by the isolation of phenol, in 8% yield, from a solution in trichloroacetic acid. The reality of this carbonium salt formation and its structure was confirmed by the isolation of its hydrolysis product, namely 4-hydroxytriphenylcarbinol, in 27% yield, from sulfuric acid solution.

$$\left[\begin{array}{c} HOC_6H_4 \\ (C_6H_5)_2 \end{array}\!\!\!\!\searrow\!\!C\right]^+ HSO_4^- + H_2O \longrightarrow \begin{array}{c} HOC_6H_4 \\ (C_6H_5)_2 \end{array}\!\!\!\!\searrow\!\!COH + H_2SO_4$$

The similarity between the absorption curves of acid solutions of 4,4'-dihydroxytetraphenylmethane and 4,4'-dimethoxytetraphenylmethane (Figs. 4 and 5) provided evidence that their reactions with acids were similar

$$\begin{array}{c} CH_3OC_6H_4 \\ (C_6H_5)_2 \end{array}\!\!\!\!\searrow\!\!C-C_6H_4OCH_3 + HX \longrightarrow \left[\begin{array}{c} CH_3OC_6H_4 \\ (C_6H_5)_2 \end{array}\!\!\!\!\searrow\!\!C\right]^+ X^- + C_6H_5OCH_3.$$
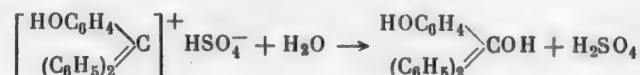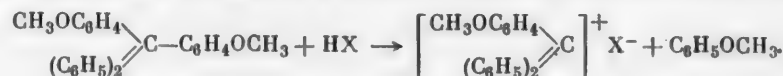
Thus, the results of our investigation showed that the color of acid solutions of tetraphenylmethane, and of its hydroxy and methoxy derivatives, was due in every case to the formation of a carbonium salt by a splitting of the molecule at a methane bond.
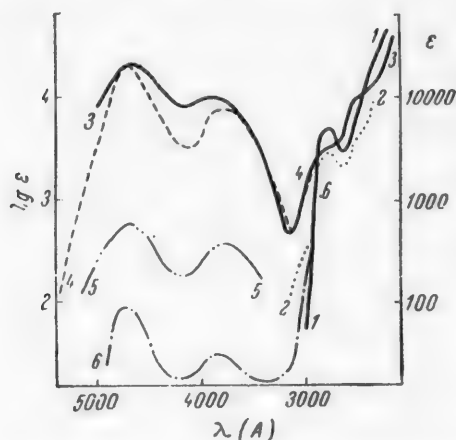
Fig. 5. 4,4'-Dimethoxytetraphenylmethane.
1) In C_2H_5OH; 2) in C_2H_5OH + $NaOC_2H_5$;
3) in concentrated H_2SO_4; 4) in 30%
H_2SO_4 in CH_3COOH; 5) in 44% H_3PO_4
in CH_3COOH; 6) in 90% CCl_3COOH.
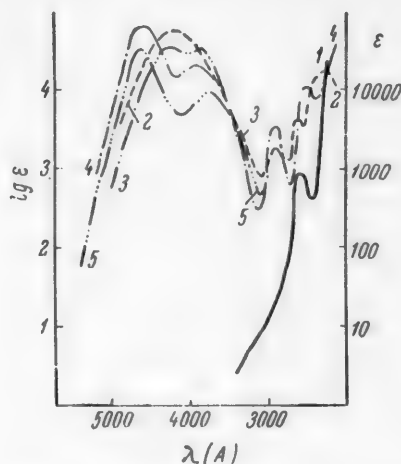
Fig. 6. Triphenylcarbinol. 1) In
C_2H_5OH; 2) in concentrated H_2SO_4;
3) in 30% H_2SO_4 in CH_3COOH.
4-Hydroxytriphenylcarbinol. 4)
In concentrated H_2SO_4; 5) in 30%
H_2SO_4 in CH_3COOH.

On this basis, we assumed that the interaction with acids of tetrasubstituted aromatic derivatives of methane took place similarly to give carbinol bases, and that this reaction was of the normal type of acid-base interaction. These processes are reversible reactions for the well-known syntheses of a number of aromatic derivatives of methane from the corresponding carbinols, e.g., of benzene [20], phenol [21] and aniline [22].

EXPERIMENTAL

Splitting of Hydroxy Derivatives of Tetraphenylmethane by

Trichloroacetic Acid

The substance to be investigated was placed in a 100 ml flask together with a fivefold excess of trichloroacetic acid. The flask was heated in a glycerin bath for 6 hours, so that the solution boiled gently. The dark

solution was then transferred to another flask fitted for steam distillation. Distillation was continued as long as a portion of distillate gave a precipitate with bromine water. The aqueous distillate was then treated with bromine water until a weak yellow color persisted. The distillate, with precipitate, was allowed to stand until the next day and then filtered. The residue was dried and weighed. In all cases, we obtained a substance of m. p. 92-93° [17], which showed no change in melting point when mixed with a sample of tribromophenol. From 5 g of 4-hydroxytetraphenylmethane we obtained 0.5 g of tribromophenol, corresponding to a 10.3% yield of phenol, and from 5 g of 4,4'-dihydroxytetraphenylmethane we obtained 0.43 g of tribromophenol, corresponding to 8.0% of phenol.

Splitting of 4,4'-Dihydroxytetraphenylmethane with Concentrated Sulfuric Acid

Concentrated sulfuric acid, 80 ml, was added a little at a time to 4 g of 4,4'-dihydroxytetraphenylmethane in a dry 250 ml flask. The substance became yellow and then orange colored, and, after 30 minutes continuous shaking, dissolved completely to give a clear red solution. The solution was allowed to stand for 2.5 hours and then poured in a fine stream, with continuous stirring, into cold water. An orange precipitate formed and was filtered off after two days. The dried product weighed 0.85 g. It melted at 105-108°, and at 135-136° after recrystallization from aqueous alcohol. Further recrystallization from 50% acetic acid gave a substance of m. p. 138-139° [1], which showed no depression of melting point when mixed with a sample of 4-hydroxytriphenyl-carbinol. The substance was thus identified as 4-hydroxytriphenylcarbinol. The yield was 27%.

The compounds required for the investigation were synthetized and purified by known literature methods.

SUMMARY

1. A systematic investigation has been made of the absorption spectra of tetraphenylmethane, and of its hydroxy and methoxy derivatives, in acid solutions.

2. From the absorption spectra of the acid solutions it was established that the formation of colors was associated with the splitting of the molecules of these compounds to form carbonium salts, by acid-base interaction.

3. These conclusions on the splitting of the molecules of hydroxy derivatives of tetraphenylmethane were confirmed chemically, by isolation of phenol and of the hydrolysis products of the carbonium salts.

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INVESTIGATION OF THE DEGREE OF ACTIVITY OF THE METHYL GROUP IN DERIVATIVES OF SYMMETRICAL METHYLTRIAZINE

I. CONDENSATION WITH ALDEHYDES

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With the object of studying the mobility of the methyl group hydrogen atoms in different derivatives of sym-methyltriazine (I), in this paper we investigated the condensation reactions of these compounds with aldehydes.

$$
\begin{array}{l}
A : R' = R'' = OH \\
B : R' = NH_2, \ R'' = OH \\
C : R' = R'' = NH_2 \\
D : R' = R'' = OCH_3
\end{array}
$$
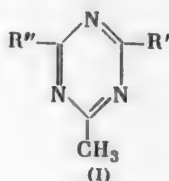
The following triazines were investigated: dihydroxy- (IA), aminohydroxy- (IB), diamino- (IC), and dimethoxy-sym-methyltriazine (ID). The aldehydes used were benzaldehyde, o- and m-nitro- and p-dimethylaminobenzaldehydes.

The investigation of the degree of activity of methyl groups in sym-methyltriazine derivatives was a continuation of similar work with compounds of the pyridine and pyrimidine series [1]. In this earlier work we showed that under otherwise similar conditions the methyl group of 4-methylpyrimidine derivatives was more active than in the corresponding derivatives of 2- and 4-methylpyridines [1]. In 4-methylpyrimidine derivatives both the heterocyclic N atoms were conjugated with the methyl group, so that the latter was subjected to a double activating influence, whereas, with the 2- or 4-methylpyridines, the methyl group was only under the activating influence of one heterocyclic N atom.

There are three nitrogen atoms to conjugate with the methyl group in the symmetrical methyltriazine derivatives; it would therefore be expected that the methyl group in these compounds would be more active than in the corresponding pyrimidines.

The choice of the substituents R' and R'' in the triazine derivatives (I) was based on the following considerations. It was found, with the pyridine and pyrimidine series, that an electron donor substituent (OH, NH_2, etc.), in the 2 or 6 position of the heterocyclic ring, considerably reduced the activity of a methyl group in the 4 position. The deactivating influence of the electron donor group was more pronounced the greater the mobility of the unshared pair of electrons in the group.

The methyl group in unsubstituted 4-methylpyrimidine was so active that its hydrogen atoms could take part in nitrogen coupling with various diazo compounds [1].

The use of unsubstituted methylpyrimidines and methyltriazines might therefore be unsuitable for comparison, since the ability to couple with nitrogen is indeed the criterion for the highest activity of methyl groups.

Also, unsubstituted symmetrical methyl triazine is difficult to prepare and is unstable; it hydrolyzes readily [2]. In this respect the hydroxy and amino derivatives of pyrimidine and triazine were more suitable for comparing differences in activity of their methyl substituent groups.

It was also of interest to compare the activities of the methyl groups in the different compounds of the triazine series. If, in this series, as with the pyrimidines, the activity of the methyl group decreased in proportion to the increase in electron donor power of the substituent conjugating with the heterocyclic N atom, then the greatest activity of the methyl group should have been shown by dihydroxy- (IA) or dimethoxymethyltriazine (ID) and the least activity by diaminomethyltriazine (IC).

Up till now no special papers have been published on investigations of the activity of the methyl group in symmetrical methyltriazines. However, there have been isolated statements on the capacity of these compounds to take part in a condensation reaction with aromatic aldehydes. Condensation products of diaminomethyltriazine with benzaldehyde, p-hydroxy- and o-nitrobenzaldehydes, anisaldehyde and vanillin were first obtained in 1907 [3]. In the subsequent 50 years the only such condensation products described were of trimethyltriazine and dimethylphenyltriazine with benzaldehyde [4, 5].

To prepare the methyltriazine derivatives, we used methods described in the literature [for (IB) and (IC)] and new methods developed by us [for (IA) and (ID)].

We first examined the interaction of aminohydroxymethyltriazine with different aromatic aldehydes: benzaldehyde, o-, m-, and p-nitrobenzaldehydes and p-dimethylaminobenzaldehyde. The reactions were carried out under various conditions, so as to find out which conditions were the most suitable for a comparative investigation of the capacities of all the above triazines to condense with aldehydes.

In order to achieve condensation of aminohydroxymethyltriazine with benzaldehyde, it was necessary to use excess of the latter and to carry out the reaction at its boiling point. The product from this condensation was difficult to purify. Condensation with o-, m , and p-nitrobenzaldehydes was carried out with fused reagents or with boiling alcoholic solutions (with and without addition of piperidine or hydrochloric acid). It was found that condensation took place with fused reagents at 200° in the course of half an hour. But, with these conditions, purification of the products was difficult and involved considerable loss. It was easiest to carry out the condensation of aminohydroxymethyltriazine with p-dimethylaminobenzaldehyde in 5% HCl, at 100°, over a period of 30-40 minutes.

All the other triazines investigated condensed with p-dimethylaminobenzaldehyde under the same conditions, whereupon the colors of the resulting solutions varied from red to violet-red.

$$\text{(I) (A, B, C, D)}$$

$$\text{(II) (A, B, C)}$$

A : R' = R'' = OH
B : R' = NH$_2$, R'' = OH
C : R' = R'' = NH$_2$
D : R' = R'' = OCH$_3$
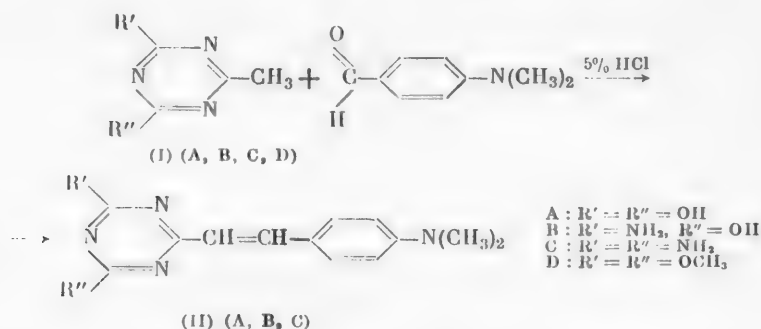
p-Dimethylaminostyryldihydroxytriazine (IIA) formed a monohydrochloride which deposited from the solution on standing in the form of long, silky, dark blue crystals. The corresponding aminohydroxy and diamino derivatives (IIB) and (IIC) did not separate from solution under these conditions. To obtain their salts it was necessary to add the minimum quantity of concentrated HCl to the reaction mixture and to heat on a water bath for 40-50 minutes. Recrystallization of the condensation product (IIC) from diaminomethyltriazine, using HCl of different strengths, gave the following crystalline salts: a pale brown monohydrochloride and a white dihydrochloride. The condensation product (IIB) of aminohydroxymethyltriazine was isolated in the form of a rose-violet dihydrochloride. All the hydrochlorides obtained were easily hydrolyzed; they acquired a red color by the action of water, or even on standing in air.

All the p-dimethylaminostyryl derivatives (IIA, B and C) could be obtained in the free base form by addition of soda to solutions of their salts in dilute HCl. They were yellow to orange in color, and were practically insoluble in water.

When dimethoxymethyltriazine reacted with p-dimethylaminobenzaldehyde under the same conditions (i.e., in 5% HCl, at 100° for 30-40 minutes), hydrolysis of both the methoxy groups occurred as well as the condensation reaction. The product was found to be dihydroxy-p-dimethylaminostyryltriazine, identical with the (IIA) described above, and was isolated in the form of blue crystals of monohydrochloride.

It is known that acid hydrolysis of methoxy derivatives occurs very readily in the sym-triazine series. For example, Schaefer et al. [10], on heating dimethoxyanilino-sym-triazine for 1.5 hours, at 150-210°, in the presence of 4% p-toluenesulfonic acid, obtained a product with one hydroxyl group, to which they ascribed the structure
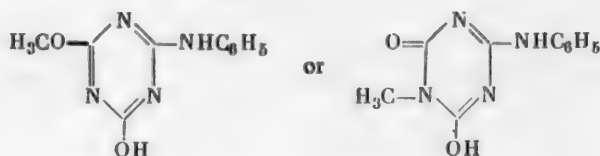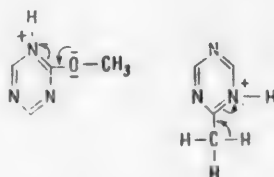

The relative ease of hydrolysis of methoxy groups in similar compounds may be explained by the simultaneous action of the three hetero-atoms in producing a shift of the unshared pair of electrons, from the oxygen atom to the triazine ring. This shift is reinforced in acid media by the appearance of additional charges on the hetero-atoms, for instance:

In the same way, the acid medium obviously makes possible an increase in mobility of the hydrogen atoms of the methyl group.

Condensation proceeded differently when dimethoxymethyltriazine (ID) was fused with p-dimethylamino-benzaldehyde in the presence of an alkaline catalyst. Thus, when the reaction was carried out in the presence of piperidine, at 170-180°, for a period of 1 hour, an orange-colored crystalline product (m. p. 257-259°) was formed, which, according to the analytical results, represented a condensation product. Under these conditions there was no splitting off of methyl groups. This condensation product was quite stable toward acid hydrolysis, and was not transformed to the corresponding dihydroxy derivative (IIA) when boiled with 5% HCl: it was obtained back unchanged on neutralization. This suggested that, when the condensation was carried out at 170 to 180°, the methyl radicals migrated from the methoxy groups in the 2 and 6 positions to the heterocyclic nitrogen atoms in positions 1 and 3 (IIE).

(IIE)
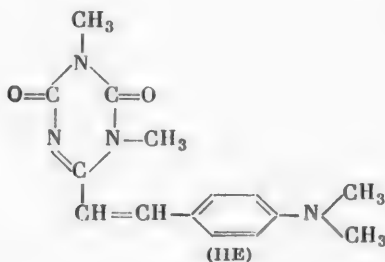
An analogous regrouping in the sym-triazine series, described by Schaefer et al. [10], was the conversion of 2-butylamino-4,6-dimethoxy-sym-triazine (III) at 170-180° into 2-butylamino-1,5-dimethyl-4,6-diketo-1,4,5,6-tetrahydro-sym-triazine (IV), whose structure was shown by its hydrolysis to dimethyl isocyanurate (V).
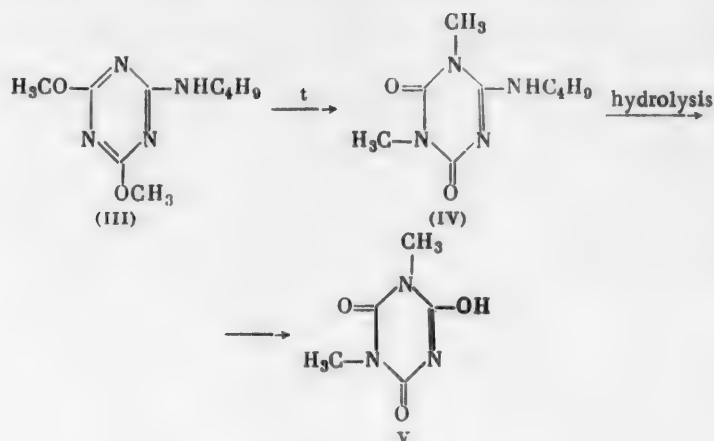
TABLE 1
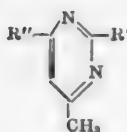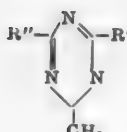
Condensation Products of 4-Methyltriazine with p-Dimethylaminobenzaldehyde

No.	Initial triazine	p-Dimethylaminostyryl derivatives		
		base	salt	
			Monohydro-chloride (II)·HCl	Dihydro-chloride (II)·2HCl
1	A : R′=R″=OH, white	Orange, m. p. 300° (decomp)	Dark-blue, m.p. 270-271° (decomp)	—
2	B : R′=NH₂; R″=OH, yellow-white	Yellow-orange, m.p. 314 to 316° (decomp)		Rose-violet (with H₂O), m.p. 267 to 269° (decomp)
3	C : R′=R″=NH₂, white, m.p. 265°	Yellow, m.p. 250-253°	Light-brown (with ½ H₂O) m.p. above 300° (de-comp)	White (with H₂O), up above 300° (decomp)
4	D : R′=R″=OCH₃, white, m. p. 69—72°	Rose-orange, m.p. 257-259°	—	—

To check our hypothesis we heated dimethoxymethyltriazine in the presence of piperidine, in a sealed tube, for 1 hour, at 170-180°, and condensed the product with p-dimethylaminobenzaldehyde, in 5% HCl, at 100°. The condensation product, isolated from the resulting solution by addition of soda, was identical with substance (IIE). The properties of the condensation products obtained are shown in Table 1. A comparison of the activities of the methyl derivatives of sym-triazine and pyrimidine is given in Table 2.

TABLE 2

Condensation Products of 4-Methylpyrimidine, and the Corresponding Products of 4-Methyl-triazine, with p-Dimethylaminobenzaldehyde

	$R'=R''=OH$	$R'=NH_2$ $R''=OH$	$R'=R''=NH_2$	$R'=R''=OCH_3$
(pyrimidine structure)	Condenses* [11]	Does not condense [12]	Does not condense	—
(triazine structure)	The same	Condenses	Condenses	Condenses**

* Condensation took place in a boiling aniline medium.
** Hydrolysis of the methoxy groups occurred in 5% hydrochloric acid; migration of methyl groups occurred on fusion in the presence of piperidine.

All the methyltriazine derivatives investigated contained a more reactive methyl group than that in the corresponding methylpyrimidine derivatives, and were capable of condensing with p-dimethylaminobenzaldehyde; the latter reaction could not, therefore, give a measure of differences in the deactivating influences of OH and NH_2 groups on the methyl group. Differences might be revealed by investigating the capacity of these triazines to couple with nitrogen, and this will be dealt with in a subsequent paper.

EXPERIMENTAL

Dihydroxymethyltriazine (IA). A mixture of 10 g (0.078 mole) of aminohydroxymethyltriazine (IB) and 10 g concentrated H_2SO_4 was heated on a sand bath, at 160-180°, for 0.5 hour [6]. The cooled contents of the flask were digested with water. A sample of the reaction mixture (1 ml) was titrated with 0.1 N NaOH, and the calculated quantity of $Pb(OCOCH_3)_2$ to remove the H_2SO_4 was added. The precipitate was filtered off after a few hours. Any residual lead was removed by passing H_2S through the solution. The PbS was filtered off, and the solution was evaporated to dryness on a water bath. The residue was treated with a little concentrated HCl and extracted with acetone. The residue of dihydroxymethyltriazine hydrochloride was filtered off and washed with acetone. It was recrystallized from 5% HCl. Yield 2.2 g (22%).

Condensation of dihydroxymethyltriazine with p-dimethylaminobenzaldehyde. A solution of 0.82 g (0.005 mole) of the hydrochloride of dihydroxymethyltriazine (IA) and 0.75 g (0.005 mole) of p-dimethylamino-benzaldehyde in 10 ml of 5% HCl was heated, at 100°, for 0.5 hours. The solution acquired an intense red-violet color. Beautiful dark blue crystals, in the form of silky fibers, separated from the solution after standing overnight. Yield 0.52 g (36%). M. p. 270-271° (decomp.) (from 5% HCl). The product was the monohydrochloride of 2,6-dihydroxy-4-(p-dimethylaminostyryl)-sym-triazine (IIA).

Found %: C 52.60, 53.01; H 5.02, 5.35; N 19.18, 18.79. $C_{13}H_{14}O_2N_4 \cdot HCl$. Calculated %: C 52.97; H 5.13; N 19.01; Cl 12.03.

The base 2,6-dihydroxy-4-(p-dimethylaminostyryl)-triazine. Gentle heating was used to dissolve 0.3 g of the monohydrochloride of (IIA) in 23 ml of 5% HCl. The solution was neutralized with soda to a weak alkaline reaction with litmus. The orange red precipitate formed was filtered off, washed with water and dried. Yield 0.2 g (76%). The product was poorly soluble in alcohol, dioxane or glacial acetic acid; it was insoluble in water or toluene. It was purified by boiling with dioxane and then with methyl alcohol. M. p. approximately 300° (decomp.).

Found %: C 60.43, 60.47; H 5.61, 5.61; N 21.52, 21.40. $C_{13}H_{14}O_2N_4$. Calculated %: C 60.44; H 5.46; N 21.69.

Condensation of aminohydroxymethyltriazine with p-dimethylaminobenzaldehyde. A mixture of 3.81 g (0.03 mole) of aminohydroxymethyltriazine (IB), 4.47 g (0.03 mole) of p-dimethylaminobenzaldehyde and 8 ml of concentrated HCl was heated on a water bath for 1 hour. A precipitate deposited from the cherry red solution. After cooling, the pale lilac-colored precipitate was filtered off, washed with concentrated HCl and dried in a desiccator. Yield 1.9 g. The precipitate became red on standing in air, or on addition of water. M. p. of dihydrochloride 267-269° (decomp.) (from 2-10% HCl).

Found %: C 45.08, 44.8; H 5.71, 5.72; N 20.38, 20.08; Cl 20.17, 20.29. $C_{13}H_{15}ON_5 \cdot 2HCl \cdot H_2O$. Calculated %: C 44.83; H 5.50; N 20.11; Cl 20.36.

The base 2-amino-6-hydroxy-4-(p-dimethylaminostyryl)-triazine. Gentle heating was used to dissolve 0.5 g of the dihydrochloride of 2-amino-6-hydroxy-4-(p-dimethylaminostyryl)-triazine (IIB) in 15 ml of 5% HCl. The solution was neutralized with soda. The yellow-orange precipitate formed was filtered off, washed with water and dried. Yield 0.4 g (about 100%). It was poorly soluble in the usual organic solvents. It was purified by boiling with alcohol. M. p. 314-316° (decomp.).

Found %: C 60.54, 61.04; H 5.29, 5.40; N 27.11, 26.83. $C_{13}H_{15}ON_5$. Calculated %: C 60.67; H 5.87; N 27.22.

Recrystallization from glacial acetic acid gave an orange-yellow deposit of the acetate. M. p. 309-311° (decomp.).

Found %: C 56.42, 56.75; H 5.66, 5.70; N 22.14, 22.29. $C_{13}H_{15}ON_5 \cdot CH_3COOH$. Calculated %: C 56.76; H 6.03; N 22.07.

Condensation of diaminomethyltriazine with p-dimethylaminobenzaldehyde. Diaminomethyltriazine (IC) was obtained by heating guanidine acetate to 220-230° and extracting the melt with boiling water [7]. A mixture of 1.26 g (0.01 mole) of diaminomethyltriazine, 1.49 g (0.01 mole) of p-dimethylaminobenzaldehyde and 3 ml of concentrated HCl was heated on a water bath for 1 hour. The mixture was cooled, and the deposit was filtered off, washed with concentrated HCl and dried in a desiccator over NaOH. Yield 0.37 g. Color pale lilac. A pale rose-colored deposit separated on the addition of water to the dark red mother liquor. Yield 1.2 g. Both salts reddened on exposure to air or addition of water. The monohydrochloride was obtained by recrystallization of these salts from 2% HCl.

Found %: C 51.47, 51.94; H 5.89, 6.07; N 27.64, 27.81; Cl 12.42. $C_{13}H_{16}N_6 \cdot HCl \cdot \frac{1}{2} H_2O$. Calculated %: C 51.72; H 6.01; N 27.85; Cl 11.75.

Recrystallization from 10% HCl gave the white dihydrochloride.

Found %: C 45.13, 45.34; H 5.94, 5.91; N 23.86. $C_{13}H_{16}N_6 \cdot 2HCl \cdot H_2O$. Calculated %: C 44.95; H 5.80; N 24.20; Cl 20.42.

The base 2,6-diamino-4-(p-dimethylaminostyryl)-triazine. Gentle heating was used to dissolve 0.5 g of the dihydrochloride of 2,6-diamino-4-(p-dimethylaminostyryl)-triazine (IIC) in 30 ml of 2% HCl. The solution was neutralized with soda. The yellow-colored precipitate formed was filtered off, washed with water and dried. Yield 0.37 g (about 100%). The substance contained one molecule of alcohol after recrystallization from the latter. This alcohol was removed by drying at 110°. M. p. 250-253°.

Found %: C 60.81, 61.25; H 6.25, 6.52; N 32.55, 32.57. $C_{13}H_{16}N_6$. Calculated %: C 60.90; H 6.29; N 32.79.

Dimethoxymethyltriazine (ID) is not described in the literature. It was synthesized by first allowing trichlorotriazine to react with methyl magnesium bromide to give methyldichlorotriazine [8]. By carrying out this reaction at 0°, we succeeded in replacing only one chlorine atom in cyanuric trichloride by a methyl group, because the mobility of the chlorine atoms in the resulting methyldichlorotriazine was reduced in comparison with their mobility in the original cyanuric trichloride (see [9]).

Slight warming was used to dissolve 0.5 g (0.003 mole) of dichloromethyltriazine in 5 ml of methyl alcohol. The cooled solution was treated with 5 ml of 10% NaOH in methanol [5]. The deposit of NaCl was filtered off, and the solution was evaporated at room temperature. The residue was extracted with ether, and the ether was evaporated off from the extract at room temperature. Yield 0.32 g (70%). M. p. 69-72°. The product was readily soluble in alcohol, ether, dioxane and benzene. It smelled strongly like mouse excrement and was white in color.

Found %: C 46.38, 46.18; H 5.57, 5.59; N 26.78. $C_6H_9O_2N_3$. Calculated %: C 46.46; H 5.85; N 27.09.

Condensation of dimethoxymethyltriazine with p-dimethylaminobenzaldehyde in an acid medium at 100°. A mixture of 0.39 g (0.0025 mole) of dimethoxymethyltriazine (ID), 0.38 g (0.0025 mole) of p-dimethyl-aminobenzaldehyde and 7 ml of 5% HCl was heated at 100° for 0.5 hour. The solution acquired a red-violet color. The deposit, in the form of long, dark blue, silky fibers, was filtered off, washed with 5% HCl and dried. Yield 0.25 g (32%). M. p. 268-269° (decomp.) (from 5% HCl). A sample mixed with the known monohydro-chloride of 2,6-dihydroxy-4-(p-dimethylaminostyryl)-triazine gave no melting point depression.

Found %: N 18.96, 18.87; Cl 12.20, 12.18. $C_{13}H_{14}O_2N_4 \cdot HCl$. Calculated %: N 19.01; Cl 12.03.

Condensation of dimethoxymethyltriazine with p-dimethylaminobenzaldehyde in an alkaline medium at 170-180°. A mixture of 0.39 g (0.0025 mole) of dimethoxymethyltriazine (ID) with 0.41 g (0.0027 mole) of p-dimethylaminobenzaldehyde was heated to fusion, treated with one drop of piperidine and heated to 170-180°, for 1 hour. The product was cooled, treated with 10 ml of dioxane, heated to boiling and filtered. The red-orange deposit, formed in the filtrate, was filtered off and dried. Yield 0.17 g (24%). M. p. 257-259° (from dioxane).

Found %: C 63.29, 62.90; H 6.10, 5.89; N 19.56, 19.51. $C_{15}H_{18}O_2N_4$. Calculated %: C 62.94; H 6.34; N 19.58.

The product was evidently 1,3-dimethyl-2,6-diketo-4-(p-dimethylaminostyryl)-tetrahydro-sym-triazine.

Isomerization of dimethoxymethyltriazine and condensation of the isomerization product with p-dimethyl-aminobenzaldehyde in an acid medium. A drop of piperidine was added to 0.31 g (0.002 mole) of dimethoxy-methyltriazine (ID), and the mixture was heated for an hour, in a sealed tube, at 170-180°. The product was cooled and dissolved, by heating, in 2 ml of methyl alcohol. The solution was evaporated to dryness on a water bath. The resulting viscous, violet-colored liquid did not have the smell characteristic of the original dimethoxy-methyltriazine.

A mixture of 0.3 g of this substance and 0.3 g of p-dimethylaminobenzaldehyde was dissolved in 5 ml of 5% HCl, and heated at 100° for 0.5 hour. The red-violet colored solution was neutralized with soda. The orange colored deposit formed was filtered off, treated with water, heated for some time at 60-70° and filtered off. It was purified by boiling with alcohol and recrystallization from dioxane. Yield 0.04 g (7%). M. p. 257-259°. It was identical with 1,3-dimethyl-2,6-diketo-4-(p-dimethylaminostyryl)-tetrahydro-sym-triazine (see above). A sample gave no mixed melting point depression with this.

SUMMARY

1. An investigation has been made of the interaction of sym-methyltriazine derivatives, containing OH and NH_2 groups in the 2 and 6 positions of the ring, with p-dimethylaminobenzaldehyde. It has been shown that all the methyltriazines investigated were capable of taking part in a condensation reaction, giving the corresponding dimethylaminostyryl derivatives of sym-triazine.

2. It was found that during the interaction of dimethoxymethyltriazine with p-dimethylaminobenzalde-hyde in an acid medium hydrolysis of both methoxy groups occurred at the same time as the condensation. An intramolecular regrouping occurred, in parallel with the condensation, on heating in an alkaline medium.

3. The hydrochlorides and the corresponding bases, 2,6-dihydroxy-2-amino-6-hydroxy- and 2,6-diamino-4-(p-dimethylaminostyryl)-triazines were obtained. Also obtained was 1,3-dimethyl-2,6-diketo-4-(p-dimethyl-aminostyryl)-tetrahydro-sym-triazine.

4. It has been shown that under fixed uniform conditions, the hydrogen in the methyl group of the methyltriazine derivatives is more mobile than in the corresponding methylpyrimidine derivatives.

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THE SYNTHESIS OF CARBOXYLIC ACID DERIVATIVES UNDER CONDITIONS OF ACID CATALYSIS, FROM CARBON MONOXIDE, OLEFINS AND ACYLATING COMPOUNDS

II. SYNTHESIS OF ESTERS FROM ISOBUTENE AND BUTENE [1]

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The synthesis of carboxylic acids and their esters from olefins, carbon monoxide and water, or alcohols, in the presence of acid catalysts, is usually carried out at elevated temperature — 100-350° — and high pressure — 500-1000 atmos. In all cases, it is considered necessary to have all three components present together in the initial reaction mixture. In these syntheses, however, the desired product is always obtained in low yield [2]. In contradistinction to this, Koch [3], in 1955, achieved the synthesis of carboxylic acids in two stages: in the first stage the olefin reacted with CO in the presence of concentrated H_2SO_4, and water was added in the second stage. Acids were obtained in good yield under relatively mild conditions, at temperatures from 0-50° and pressures from 1-100 atmos.

We have proposed that the first stage consists of the formation of an acylsulfonic acid $C_nH_{2n+1}COHSO_4$ from the CO, olefin and sulfuric acid, and that, in the second stage, this reacts with water, alcohols or other acylating agents to form carboxylic acids, esters or other derivatives [1]. Acylsulfonic acids of this type were obtained by Meyer [4], as long ago as 1903, by dissolving carboxylic acids in concentrated H_2SO_4. From these he obtained methyl esters of the carboxylic acids, in good yield, by addition of methyl alcohol. In a previous paper [1] we presented preliminary data on a successful new synthesis of esters from CO, olefins, and alcohols in two stages and on the mechanism of this process.

In this paper we present experimental results on the carboalkoxylation of isobutene and butene. The first stage of the syntheses of the esters was carried out by Koch's method of the interaction of olefins with CO in the presence of concentrated H_2SO_4. In the second stage, we added alcohols instead of water to the reaction mixture, and obtained excellent yields of carboxylic acid esters. In this way, we confirmed experimentally our hypothesis as to the formation of acylsulfonic acids from CO, olefins and concentrated H_2SO_4, since, on the addition of alcohols in the second stage, we achieved their esterification as described by Meyer. We obtained different esters of a given acid by the use of different alcohols. In experiments with a single alcohol, we obtained a mixture of esters, with one or two clearly predominating. The products were separated by fractionation up a column. The esters were identified by their physical constants, including the melting points of the anilides, obtained by reaction of the esters with anilinomagnesium bromide, which was prepared from the desired Grignard reagent and aniline [5].

$$2RNHMgX + R'COOR'' \longrightarrow R'C(OMgX)(NHR)_2 \xrightarrow{H_2O}$$
$$\longrightarrow R'CONHR + RNH_2 + HOMgX$$

Experiments were first carried out on the synthesis of carboxylic acids from isobutene, by Koch's method, at atmospheric pressure, and then on the synthesis of esters from isobutene and butene at atmospheric and elevated pressures. On carboxylation at atmospheric pressure (see Table 1) 100% of the isobutene reacted, but the greater part (80-85%) was converted into polymers, and only a small proportion (15-20%) gave carboxylic acids. The yield of the latter was equivalent to 10-20% of the carbon monoxide bubbled through, and to 50-70% of that which had reacted. The mixed acids obtained in these experiments were treated with diazomethane to convert them to their methyl esters, and fractionation of the latter showed the existence of 28% of trimethyl-acetic, 10% of α,α-dimethylbutyric and 1.3% of α,α-dimethylvaleric acids. Carbomethoxylation of isobutene at atmospheric pressure, using CO and methyl alcohol (Table 1, Experiment No. 6) gave a mixture of the methyl esters of the same acids in amounts 40.0, 3.6, and 2.0%, respectively.

TABLE 1
Carboxylation of Isobutene at Atmospheric Pressure

Experiment No.	Temperature	Sulfuric acid taken (liters)	Passed through (liters)		C_4H_8/CO	CO absorbed (% of original)	Products					
							polymer (ml)	carboxylic acids %				
									based on iso-butylene		based on CO	
			isobutene	CO				g	passed through	reacted	passed through	reacted
1	0°	0.5	46.5	37.6	1.2 : 1	38	46	31.5	14.9	14.9	18.6	47.8
2	20—25	0.5	59.7	163.4	1 : 2.7	16.9	60	58.5	21.6	21.6	7.8	46.5
3	20—26	0.75	47.4	208.9	1 : 4.4	20.0	62	38.0	17.6	17.6	4.0	20.1
4	—30—(—20)	0.1+0.3 SO$_2$ *	48.7	43.6	1.1 : 1	28.4	50	40.5	18.3	18.3	20.2	72.0
5	—30—(—20)	0.5+0.3 SO$_2$ *	116.5	107.4	1.1 : 1	29.9	183	84.6	16.0	16.0	17.3	58.0
6**	20—25	0.5	99.8	95.6	1 : 1	32.2	57	161.0	31.2	31.2	32.5	100.0

* In Experiments 4 and 5, 0.3 liters of liquid SO$_2$ was added to the sulfuric acid.
** In Experiment 6, the methyl esters of the carboxylic acids were obtained directly, and the table shows their yields.

Carboalkoxylation of isobutene at an initial pressure of 80 atmos gave a higher ester yield than at atmospheric pressure, equivalent to 96-100% of the CO and 62-67% of the isobutene. The yield of esters obtained from butene under the same conditions was equivalent to 81-89 and 37-38%, respectively. In the mixture of esters obtained from isobutene, CO and methyl alcohol we established the existence of the methyl esters of trimethylacetic (53%), α,α-dimethylbutyric (6.1%) and α,α-dimethylvaleric (4.7%) acids. The ethyl esters of the same acids, in amounts of 53.6 and 2%, respectively, were found in the products obtained from isobutene, CO and ethyl alcohol. The methyl esters of trimethylacetic (3.6%) and α-methylbutyric (60%) acids were found in the ester mixture synthesized from butene, CO and methyl alcohol. The ester of α-methyl-acetic acid (53.4%) was found in the ester mixture obtained from butene, CO and ethyl alcohol.

EXPERIMENTAL

The isobutene and butene used in this work were of 96-97% purity. Experiments on carboxylation at atmospheric pressure were carried out in a special apparatus (Fig. 1).

The apparatus was a 1200 cm^3 capacity glass cylinder, with a rubber stopper. The initial gas mixture of olefin and CO was passed in through a porous glass filter, A, located at the bottom of the cylinder. Above the filter was a propeller type stirrer, B (300-400 rpm). This was connected through an obliquely located rod, ending in two ball bearings and fixed to the middle of a round rubber membrane, D, whose circumference was

firmly gripped between two cones. The lower cone, of stainless steel, ended in a tube passing through the rubber bung of the cylinder. Rotation of the motor turned the stirrer as the result of the circular tilting motion of the rod. This system maintained a complete seal for 2-3 months, after which the membrane was replaced.[*]

Carboxylation of isobutene at atmospheric pressure. A 0.5-0.75 liter charge of sulfuric acid (d 1.84) was placed in the cylinder, and a mixture of CO and isobutene was passed through at 2-3 liters/hour. Experiments were discontinued overnight. The experimental conditions and the results are shown in Table 1.
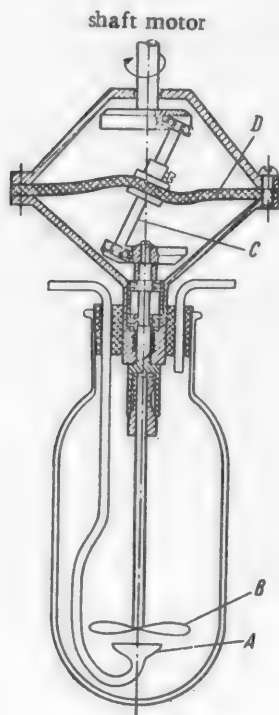
At the end of an experiment, the reaction mixture was diluted with 1 liter of water and extracted three times with ether, the ether was distilled off, and the residual oil was treated with an equal volume of 20% NaOH. The alkaline extract was evaporated to dryness, and the residue was decomposed with 20% H_2SO_4. The carboxylic acids liberated were separated, and the aqueous layer was extracted three times with ether. The acids and ether extract were combined and dried over anhydrous copper sulfate. The ether was distilled off, and the acids

Fig. 1. Apparatus for carboxylation of olefins at atmospheric pressure.
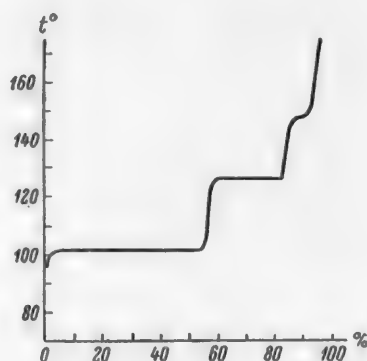
Fig. 2. Distillation curve of the methyl esters obtained by esterification of the carboxylic acids with diazomethane.

were fractionated under reduced pressure. The carboxylic acids obtained in separate experiments were combined. Altogether we obtained 425 ml of a mixture of acids distilling at 2 mm, 60% between 35 and 100° and 40% between 100 and 220°. A fraction was also obtained (b. p. 164° at 760 mm, m. p. 35°, m. p. of amide 154°, Ag salt contained 51.75% of Ag) corresponding to trimethylacetic acid (literature data: b. p. 163.7-163.8° at 760 mm, m. p. 35.3-35.5°, m. p. of amide 154° [6]; theoretical Ag content of Ag salt 51.63%). The mixed acids (340 ml) were converted into their methyl esters by treatment with a 3% ethereal solution of diazomethane, and 209 ml of the esters was fractionated from a Favorskii flask. Two fractions were obtained: the first boiled at 100-150°, 108 ml, the second at 150-120°, 98 ml. The first fraction was redistilled in a column of efficiency 40 theoretical plates. The distillation curve is shown in Fig. 2, and the physical constants of the fractions in Table 2. The second and third fractions, comprising 52.3% of the original first fraction, consisted of the methyl ester of trimethylacetic acid (literature data: b. p. 100-102°, d^{20}_4 0.891 [7], m. p. of anilide 132-133° [8]), the 5th fraction (21.3%) was the methyl ester of α,α-dimethylbutyric acid (literature data: b. p. 125-125.5° at 746 mm, d^{20}_4 0.8943, $n^{20}D$ 1.3991 [9], m. p. of anilide 91-92° [10]), and the 7th fraction (2.8%) was the

[*] The authors' thanks are due to M. D. Pushkinskii and A. A. Opekunov, who suggested this design of stirrer.

methyl ester of α,α-dimethylvaleric acid (literature data: b. p. 144-145° [11], m. p. of anilide 70.5-74.0° [12]). These esters correspond to the three plateaus on the curve of Fig. 2.

TABLE 2

Methyl Esters Obtained by Esterification of the Carboxylic Acids with Diazomethane

Fraction No.	Boiling range at 760 mm	Yield (vol.% of original mixture)	d_4^{20}	n_D^{20}	M. p. of anilide	Corresponding acid
1	73.2—101.2°	3.0	0.8508	1.3845	—	—
2	101.2—101.7	2.8	0.8727	1.3892	133°	} Trimethylacetic
3	101.7—101.8	49.5	0.8737	1.3900	133	
4	101.8—126.9	6.1	0.8794	1.3980	—	—
5	126.9—127.1	21.3	0.8819	1.4023	92	α,α-Dimethylbutyric
6	127.1—147.8	2.3	0.8823	1.4088	—	—
7	147.8—148.5	2.8	0.8825	1.4113	71	α,α-Dimethylvaleric
8	148.5—177.0	4.1	0.8822	1.4158	—	
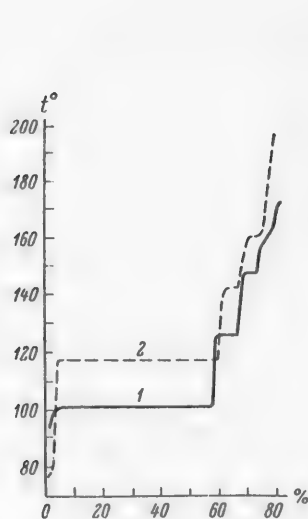
Fig. 3. Distillation curves of
the 1) methyl and 2) ethyl
esters obtained from isobutene.
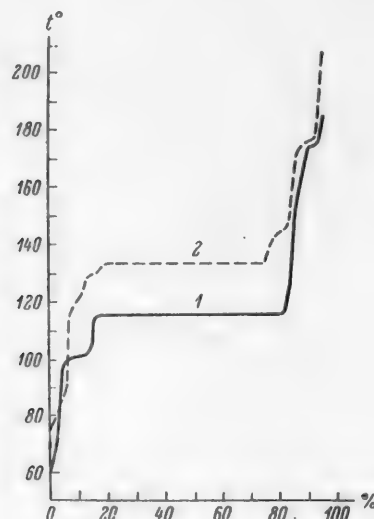
Fig. 4. Distillation curves of the
1) methyl and 2) ethyl esters
obtained from n-butene.

Carbomethoxylation of isobutene at atmospheric pressure. In Experiment 6 of Table 1, in the second stage after removal of the polymers, 400 ml of methyl alcohol and then 2 liters of water were added to the acid layer. The methyl esters of the carboxylic acids were formed, and were washed with 20% soda and dried over anhydrous copper sulfate. Distillation in a column gave the same methyl esters as were obtained from the acids by reaction with diazomethane (Table 2 and Fig. 2). The contents of the methyl esters of trimethylacetic, α,α-dimethylbutyric and α,α-dimethylvaleric acids were 40.0, 3.6, and 2.0%, respectively.

Carbalkoxylation of isobutene and butene under pressure. A 1 liter stainless steel autoclave, fitted with a turbine stirrer (800 rpm) and a drop filler, was charged with 0.5 liters of sulfuric acid and CO under 80 atmos pressure, and then 300 ml of liquid isobutene or butene in the liquid state was added from the drop filler over a period of 2 hours, during which the pressure in the autoclave fell to 20-25 atmos and the temperature rose to 40-50°. The butenes completely dissolved in the sulfuric acid, increasing its volume by 240-260 ml, without

formation of polymers. The reaction mixture was then treated with 400 ml of methanol (or 500 ml of ethanol) and 2 liters of water. The methyl (or ethyl) esters formed were dried and fractionated in a column with an efficiency of 90 theoretical plates. The experimental conditions used are shown in Table 3, and the curves and results for the distillation of the mixed esters are given in Figs. 3 and 4 and in Tables 4-7.

TABLE 3

Carbalkoxylation of Isobutene and Butene Under Pressure

Expt. No.	Sulfuric acid taken (liters)	Added		CO pressure		CO absorbed		Ester obtained		
		Liquid olefin (ml)	alcohol (ml)	initial	final	liters	% of theoretical	ml	yield (%)	
									based on initial CO	based on initial olefin
7	0.5	Isobutene 300	Methyl 400	80	17	49.5	67.0	295	100.0	67.0
8	0.5	Isobutene 300	Ethyl 500	80	19.5	47.5	64.2	305	96.5	61.7
9	0.5	Butene 300	Methyl 400	80	26	32	43.8	165	87.0	38.1
10	0.5	Butene 300	Ethyl 500	80	23	33.6	46.8	180	81.0	37.2

TABLE 4

Methyl Esters Obtained from Isobutene, Carbon Monoxide, and Methyl Alcohol

Fraction No.	Boiling range at 760 mm	Yield (vol.% of initial mixture)	d_4^{20}	n_D^{20}	Melting point of anilide	Corresponding acid
1	56.2—101.3°	4.7	0.8691	1.3872	—	—
2	101.3—101.5	53.2	0.8749	1.3895	133°	Trimethylacetic
3	101.5—126.9	2.3	0.8823	1.399)	—	—
4	126.9—127.2	6.1	0.8820	1.4020	92	α,α-Dimethylbutyric
5	127.2—147.4	1.4	0.8834	1.4072	—	—
6	147.4—149.0	4.7	0.8877	1.4125	71	α,α-Dimethylvaleric
7	149.0—157.9	1.9	0.8847	1.4130	—	—
8	157.9—172.9	6.3	0.8882	1.4158	—	—

The three plateaus in the curves of Fig. 3 correspond to the methyl (and ethyl) esters of trimethylacetic, α,α-dimethylbutyric and α,α-dimethylvaleric acids (literature data: ethyl trimethylacetate b. p. 118.0-118.2°, d_4^{18} 0.8580, $n^{20}D$ 1.3922 [13]; anilide m. p. 133° [8]; ethyl α,α-dimethylbutyrate b. p. 141.8-142.2° (746 mm), d_4^{25} 0.8601, $n^{25}D$ 1.3989 [9]; anilide m. p. 92° [10]; ethyl α,α-dimethylvalerate, anilide m. p. 71° [12]). The two plateaus of the lower curve of Fig. 4 correspond to the methyl esters of trimethylacetic and α-methylbutyric acid (literature data for the latter: b. p. 113-115° at 713 mm, d_4^{22} 0.882, $n^{20.7}D$ 1.3936 [14]; anilide m. p. 110-110.5° [15]). The large plateau of the dotted curve of Fig. 4 corresponds to ethyl α-methylbutyrate (literature data: b. p. 131-133° at 713 mm, d_4^{22} 0.864, $n^{20.7}D$ 1.3964 [14]). No depression was observed when determining the melting point of a mixture of anilides obtained from the methyl and ethyl esters of a given acid, or a mixture of either of these anilides with the anilide obtained directly from the acid.

TABLE 5

Ethyl Esters Obtained from Isobutene, Carbon Monoxide and Ethyl Alcohol

Fraction No.	Boiling range at 760 mm	Yield (vol.% of initial mixture)	d_4^{20}	n_D^{20}	Melting point of anilide	Corresponding acid
1	48.0—118.1°	4.7	0.8324	1.3755	—	
2	118.1—118.5	3.2	0.8555	1.3908	133°	} Trimethylacetic
3	118.5—118.6	50.0	0.8555	1.3909	133	
4	118.6—125.9	2.5	0.8556	1.3912	—	
5	125.9—142.0	1.0	0.8661	1.3998	—	
6	142.0—143.0	3.4	0.8647	1.4023	92	} α,α-Dimethylbutyric
7	143.0—143.8	2.9	0.8654	1.4028	92	
8	143.8—160.3	3.8	0.8771	1.4075	—	
9	160.3—161.0	2.0	0.8885	1.4080	71	α,α-Dimethylvaleric
10	161—200	5.5	0.8815	1.4122	—	

TABLE 6

Methyl Esters Obtained from Butene, Carbon Monoxide and Methyl Alcohol

Fraction No.	Boiling range at 760 mm	Yield (vol.% of initial mixture)	d_4^{20}	n_D^{20}	Melting point of anilide	Corresponding acid
1	57.9—101.1°	8.8	0.8723	1.3785	—	—
2	101.1—101.6	3.6	0.8735	1.3895	133°	Trimethylacetic
3	101.6—115.6	5.6	0.8797	1.3925	—	—
4	115.6—115.7	60.3	0.8851	1.3942	110	α-Methylbutyric
5	115.7—154.6	6.3	0.8860	1.3993	—	—
6	154.6—184.1	8.3	0.9026	1.4130	—	—

TABLE 7

Ethyl Esters Obtained from Butene, Carbon Monoxide and Ethyl Alcohol

Fraction No.	Boiling range at 760 mm	Yield (vol.% of initial mixture)	d_4^{20}	n_D^{20}	Melting point of anilide	Corresponding acid
1	72.9—132.9°	19.6	0.8581	1.3861	—	—
2	132.9—133.1	6.4	0.8685	1.3968	110°	} α-Methylbutyric
3	133.1—133.4	47.0	0.8687	1.3970	110	
4	133.4—169.4	12.2	0.8784	1.3998	—	—
5	169.4—177.5	7.5	0.9263	1.4065	—	—
6	177.5—211.1	2.1	0.9002	1.4150	—	—

SUMMARY

1. A two-stage synthesis has been achieved of esters (methyl and ethyl) from olefins (isobutene and butene), carbon monoxide and alcohols (methyl and ethyl), using sulfuric acid as a catalyst. Better yields were obtained at higher pressures (80 atmos) than atmospheric.

2. The mixture of esters obtained at elevated pressures from isobutene, with a yield equivalent to about 65% of the olefin and 100 % of the carbon monoxide, contained esters of trimethylacetic acid (53%), α,α-dimethylbutyric acid (6%) and α,α-dimethylvaleric acid (3-5%). The ester mixture obtained under the same conditions from butene, with a yield equivalent to 37-38% of the olefin and 81-89 % of the carbon monoxide, contained α-methylbutyric acid (53-60%) and trimethylacetic acid (approximately 4%).

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# SYNTHESIS OF DERIVATIVES OF SULFOPHOSPHONIC ACIDS

K. A. Petrov and A. A. Neimysheva

Sulfophosphonic acids and their derivatives have been little investigated. In the patent literature there is a description of the synthesis of the esters of sulfopropanephosphonic acid by the reaction between trialkyl-phosphites and sulfones on heating [1]. Similar substances have been synthesized in the present investigation by addition of dialkyl phosphites to ethylene sulfonic acid derivatives.

The esters, dialkylamides and acid fluoride of ethylene sulfonic acid reacted with phosphites, but did not all give the corresponding derivatives of sulfoethanephosphonic acid. Thus, when dialkyl phosphites reacted with the esters of ethylene sulfonic acid in the presence of sodium alcoholate, alkylation of the phosphites occurred to give esters of alkanephosphinic acids. No coupling occurred between dialkyl phosphites and esters of ethylene sulfonic acid, in the absence of sodium alcoholate, on prolonged heating at 160-170°.

Dialkyl phosphites added on to dialkylamides of ethylene sulfonic acid in the presence of sodium alcoholate, on heating to 110° for 6 hours, to form the esters of dialkylsulfonamidoethanephosphonic acids in 60-70% yields. The reaction did not take place under these conditions in the absence of sodium alcoholate.

Unlike the dialkylamides, the acid fluoride of ethylene sulfonic acid added on to dialkyl phosphites in the absence of sodium alcoholate. The introduction of a fluorine atom into the ethylene sulfonic acid molecule considerably increased the activity of the double bond. The reaction occurred smoothly at 110° to form the S-acid fluoride of the diester of sulfoethanephosphonic acid.

$$(RO)_2POH + CH_2{=}CHSO_2F \longrightarrow (RO)_2PCH_2CH_2SO_2F$$
$$\underset{\displaystyle O}{\overset{\displaystyle \|}{}}$$
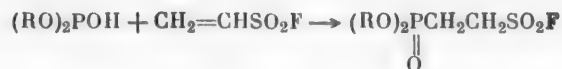
Replacement of fluorine by the alkoxy group did not take place when the acid fluoride was heated with alcohol in the presence of potassium fluoride. It was not possible to obtain fully esterified sulfoethanephosphonic acid, even by the action of sodium alcoholate on the acid fluoride. These failures possibly occurred because, under the reaction conditions, the full ester formed alkylated the sodium alcoholate. Only a part of the un-substituted acid fluoride could be recovered from the reaction mixture.

In order to obtain sulfoethanephosphonic acid derivatives, we also investigated the alkylation of trialkyl phosphites and salts of dialkyl phosphites with β-halogen-substituted disulfides. It was conjectured that reaction would occur to form bis(2-dialkylphosphono-2-methylethyl) disulfides, which would not be difficult to convert into the desired products by treatment with chlorine. However, the action of di-(β-chloropropyl) disulfide on sodium diethyl phosphite gave diethyl S-β-chloropropyl thiophosphate instead of the expected product. It must be supposed that, in this case, splitting of the S—S bond took place, according to the scheme:

$$(C_2H_5O)_2PONa + \underset{CH_3CHClCH_2S}{\overset{CH_3CHClCH_2S}{\left|\right.}} \longrightarrow \begin{array}{l} (C_2H_5O)_2P{\displaystyle\mathop{\Big\langle}^{\textstyle O}_{\textstyle SCH_2CHClCH_3}} \\ CH_3CHClCH_2SNa. \end{array}$$

Di-(β-chloropropyl) disulfide reacted with triethyl phosphite to form triethyl thiophosphate.

We did not obtain sulfophosphonates by the alkylation of sodium sulfite with esters of chloromethylphosphinic acid.

In connection with the synthesis of ethylene sulfonyl chloride, we investigated the reaction of KF with β-chloroethane sulfonyl chloride, and another interpretation is given of the mechanism of the dehydrochlorination reaction. It is known that a substance with a multiple bond is formed by the action of potassium fluoride on chlorine-substituted compounds at high temperature. For example, camphene is obtained in good yield by heating bornyl chloride with KF [2]. On this basis, it is normally considered that potassium fluoride has a dehydrochlorinating influence, and the formation of the substance with a multiple bond from the corresponding chlorine derivative, under the action of KF, is usually explained as a splitting off of the elements of hydrogen chloride. This view is based on the final result without considering the formation of intermediate products.

We consider, however, that, in the action of KF on chlorine-substituted compounds, particularly with a mobile chlorine atom, when dehydrochlorination usually occurs, the first stage is the replacement of the chlorine atom by fluorine with the formation of the corresponding fluoride.

$$CH_2ClCH_2R + KF \longrightarrow CH_2FCH_2R + KCl$$

Hydrogen fluoride then splits off from the fluoride under the influence of the KF, which acts as a hydrogen fluoride acceptor, the result being to form a substance with a multiple bond.

$$CH_2FCH_2R + KF \longrightarrow CH_2{=}CHR + KF \cdot HF$$

It is therefore dehydrofluorination which occurs in this case, and not dehydrochlorination as usually supposed. A conclusive proof of this mechanism would be the isolation of the intermediate fluoride, and the splitting off from it of hydrogen fluoride under the influence of KF. But, since the reaction rates are similar for the splitting off of hydrogen fluoride from the intermediate product and for the replacement of chlorine in the chloride by fluorine, it was not possible to isolate the intermediate product under the reaction conditions.

The possibility of isolating an intermediate fluoride, without dehydrochlorination, was examined in the case of replacement of chlorine by fluorine in β-chloroethane sulfonyl chloride. However, in no experiment was it possible to isolate β-fluoroethane sulfonyl fluoride. By the action of potassium fluoride or bifluoride at 70-100°, with or without a solvent, we obtained β-chloroethane sulfonyl fluoride, i.e., replacement of chlorine linked to carbon did not occur under these conditions.

$$ClCH_2CH_2SO_2Cl + KF \longrightarrow ClCH_2CH_2SO_2F + KCl$$

Ethylene sulfonyl fluoride was obtained on heating either β-chloroethane sulfonyl chloride or β-chloroethane sulfonyl fluoride with KF at 130-150°.

β-Chloroethane sulfonyl fluoride was previously obtained by chlorination of ethane sulfonyl fluoride in the presence of light [3], and ethylene sulfonyl fluoride was obtained by replacement of chlorine by fluorine in ethylene sulfonyl chloride [4], or by the action of potassium fluoride on β-chloroethane sulfonyl chloride [5].

EXPERIMENTAL

Dimethyl ester of dimethylsulfonamidoethanephosphonic acid. A mixture of 6.8 g ethylene dimethylsulfonamide and 5.6 g of dimethyl phosphite was treated with a solution of sodium methylate, added in drops, until heat was no longer evolved. The mixture was then heated under reflux, at 110-120° for 5 hours. A twofold distillation then gave 7.6 g (61%) of product.

B. p. 184-185° (1 mm), $n^{20}D$ 1.4690.

Found %: P 12.50; S 12.82; N 6.30. $C_6H_{16}O_5NSP$. Calculated %: P 12.65; S 13.06; N 5.71.

Dimethyl ester of diethylsulfonamidoethanephosphonic acid. A yield of 15.1 g was obtained from 12.5 g of ethylene diethylsulfonamide and 8.5 g of dimethyl phosphite, under the same conditions as above.

B. p. 177-179° (1 mm), d^{25}_4 1.2224, n^{22}D 1.4645.

Found %: P 11.49. $C_8H_{20}O_5NSP$. Calculated %: P 11.36.

When the ethylene diethylsulfonamide and dimethyl phosphite were heated together to 105-115°, in the absence of sodium alcoholate, for 6 hours, and the product was then distilled in vacuo, the starting materials were recovered quantitatively.

Diethyl ester of diethylsulfonamidoethanephosphonic acid. A mixture of 14.4 g of ethylene diethyl-sulfonamide and 12.2 g of diethyl phosphite was treated with 6 ml of sodium methylate solution, added drop by drop, during which considerable heat was evolved (the mixture was cooled in water). The reaction mixture was heated under reflux, at 120-130° for 4 hours. Vacuum distillation gave 13.5 g of product.

B. p. 171-173° (0.25 mm) or 180-182° (0.35 mm), d^{21}_4 1.1786, n^{22}D 1.4595.

Found %: P 10.24; S 10.65; N 5.51. $C_{10}H_{24}O_5NSP$. Calculated %: P 10.30; S 10.63; N 4.65.

Dimethyl ester of fluorosulfonylethanephosphonic acid. A mixture of 6.7 g of the acid fluoride of ethylene sulfonic acid and 6.7 g of dimethyl phosphite was heated under reflux, at a bath temperature of 110-120° for 3.5 hours. The reaction mixture was vacuum distilled. The yield was 5.7 g.

B. p. 127-128° (0.4 mm) or 119-121° (0.23 mm), d^{22}_4 1.4315, n^{23}D 1.4280.

Found %: P 14.19; S 14.29; F 8.35. $C_4H_{10}O_5PSF$. Calculated %: P 14.09; S 14.55; F 8.64.

It could only be distilled in a high vacuum; the aqueous solution was readily hydrolyzed by alkali. Fluorine was determined quantitatively after hydrolysis of a known weight of material by 0.5 N alkali in the cold.

Diethyl ester of fluorosulfonylethanephosphonic acid. A mixture of 5.8 g of the acid fluoride of ethylene sulfonic acid and 7.2 g of diethyl phosphite was heated under reflux, at a bath temperature of about 110° for 3 hours. The reaction mixture was then vacuum distilled to give the following fractions: 1st 30-37° (27 mm), 1.9 g (ethylene sulfonyl fluoride); 2nd 45-110° (0.2 mm), 4.4 g; 3rd 114-117° (0.2 mm), 5.3 g.

A nondistillable residue remained in the flask. The 2nd fraction was not investigated further. The 3rd fraction was redistilled to give a substance with the following properties:

B. p. 132-134° (0.5 mm), d^{19}_4 1.2917, n^{19}D 1.4260.

Found %: F 7.78; S 12.57. $C_6H_{14}O_5SPF$. Calculated %: F 7.66; S 12.90.

Diethyl S-β-chloropropyl thiophosphate. A solution of sodium diethyl phosphite, prepared from 2.3 g of sodium and 14 g of diethyl phosphite, in 50 ml of anhydrous toluene, was treated with 11 g of di(β-chloropropyl) disulfide, added drop by drop with continuous stirring. Heat was evolved and a deposit formed. The mixture was then heated, with stirring, at a bath temperature of 125-130°, for 4 hours. The reaction mixture was cooled and treated with 5 ml of water, and the coagulated deposit was filtered off; the aqueous layer was separated from the filtrate, and the toluene solution was dried over sodium sulfate. The toluene was distilled off, leaving a residue in the flask of 15.6 g. Fractional distillation of this residue gave 5.8 g of product.

B. p. 115-116° (1 mm), 131-132° (3 mm) or 122.5-123° (2 mm), d^{19}_4 1.1794, n^{19}D 1.4730.

Found %: P 12.42; S 12.80; Cl 13.64. $C_7H_{16}O_3SPCl$. Calculated %: P 12.58; S 12.98; Cl 14.40.

The same result was obtained in this case if the reaction between sodium diethyl phosphite and the disulfide was carried out in ether solution, heated for 2.5 hours.

β-Chloroethane sulfonyl fluoride. A suspension of 12 g of dry potassium fluoride in 10 ml of chloroform, plus 5 drops of water, was treated with 10 g of β-chloroethane sulfonyl chloride, added drop by drop with stirring and heating, and the reaction mixture was stirred and heated to 60-70° for 2 hours. The deposit was then filtered off and washed with ether. The solvent was distilled off from the filtrate, and the residue was vacuum distilled. The yield was 5 g after a second distillation.

B. p. 72-73° (18.5 mm), d^{22}_4 1.5072, $n^{22}D$ 1.4258.

Found %: F 12.93; Cl 23.67. $C_2H_4O_2SFCl$. Calculated %: F 12.97; Cl 24.23.

<u>Acid fluoride of ethylene sulfonic acid.</u>

a) Finely ground potassium fluoride was added to 13.8 g of β-chloroethane sulfonyl chloride. The mixture was carefully stirred and heated under reflux, at about 150° for 3-4 hours. The product was then distilled at 50 mm pressure from a water bath. A second distillation gave 7.6 g of ethylene sulfonyl fluoride.

B. p. 48° (45 mm), d^{22}_4 1.3227, $n^{22}D$ 1.3802.

Found %: F 17.05. $C_2H_3O_2SF$. Calculated %: F 17.27.

It was easily hydrolyzed by alkali in aqueous solution; it strongly irritated the mucous membrane of the eyes.

b) A mixture of 5.6 g of β-chloroethane sulfonyl fluoride and 4.5 g of finely divided potassium fluoride was heated under reflux, at 130-140° for 3 hours. The product was then distilled at 50 mm pressure, from a water bath. A second distillation gave 3 g of product. B. p. 49-52° (48 mm) or 117° at atmospheric pressure.

SUMMARY

1. We have investigated the reaction between dialkyl phosphites and the dialkylamides and acid fluoride of ethylene sulfonic acid; the previously unknown S-dialkylamides and S-acid fluorides of the diesters of sulfo-ethanephosphonic acid were obtained.

2. It has been shown that the action of KF on β-chloroethane sulfonyl chloride at 150° gives ethylene sulfonyl fluoride, and, at lower temperatures or in solution, gives β-chloroethane sulfonyl fluoride.

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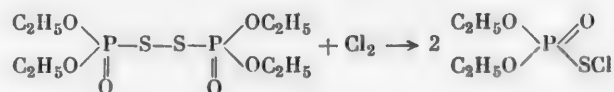[5] German Patent 952,803; Ref. Zhur. Khim. (18), 61, 657 (1957).

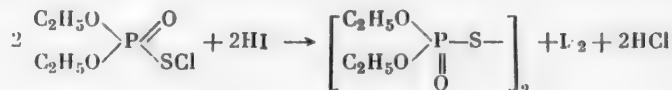* Original Russian pagination. See C. B. Translation.

DIETHYL S-CHLOROTHIOPHOSPHATE

K. A. Petrov and A. A. Neimysheva

This paper is concerned with the synthesis and a study of the properties of diethyl S-chlorothiophosphate.[*] We achieved the synthesis of this substance by splitting tetraethyl bisthiophosphate [1] with chlorine or sulfuryl chloride at room temperature.

$$\begin{matrix} C_2H_5O \\ C_2H_5O \end{matrix} \!\! > \!\! P \!\! -\!\! S\!\! -\!\! S\!\! -\!\! P \!\! < \!\! \begin{matrix} OC_2H_5 \\ OC_2H_5 \end{matrix} + Cl_2 \longrightarrow 2\ \begin{matrix} C_2H_5O \\ C_2H_5O \end{matrix} \!\! > \!\! P \!\! < \!\! \begin{matrix} O \\ SCl \end{matrix}$$
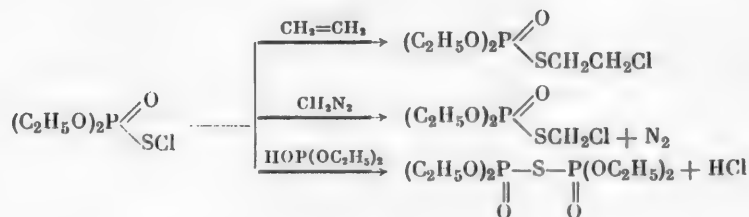
Diethyl S-chlorothiophosphate is unstable and relatively easily loses its active chlorine, being converted into an undistillable liquid. Its high reactivity can be made use of for introducing the dialkyl thiophosphate residue into different compounds. Its chemical properties closely resemble those of sulfenyl chlorides. Thus, it liberates iodine from an acidified solution of potassium iodide, being converted to the disulfide.

$$2\ \begin{matrix} C_2H_5O \\ C_2H_5O \end{matrix} \!\! > \!\! P \!\! < \!\! \begin{matrix} O \\ SCl \end{matrix} + 2HI \longrightarrow \left[\begin{matrix} C_2H_5O \\ C_2H_5O \end{matrix} \!\! > \!\! P \!\! -\!\! S\!\! - \right]_2 + I_2 + 2HCl$$

Diethyl S-chlorothiophosphate adds on to ethylene and to cyclohexene, and reacts with diazomethane, to form O,O-diethyl S-β-chloroethyl, O,O-diethyl S-β-chlorocyclohexyl and O,O-diethyl S-chloromethyl thiophosphates, respectively.

The reaction of sulfenyl chlorides with diazomethane was investigated by us previously in the synthesis of α-halogeno sulfides [2].

Diethyl S-chlorothiophosphate reacts like sulfenyl chlorides with dialkyl phosphites. The reaction with diethyl phosphite gives tetraethyl pyrothiophosphate.

$$(C_2H_5O)_2P \!\! < \!\! \begin{matrix} O \\ SCl \end{matrix} \begin{cases} \xrightarrow{CH_2=CH_2} (C_2H_5O)_2P \!\! < \!\! \begin{matrix} O \\ SCH_2CH_2Cl \end{matrix} \\ \xrightarrow{CH_2N_2} (C_2H_5O)_2P \!\! < \!\! \begin{matrix} O \\ SCH_2Cl \end{matrix} + N_2 \\ \xrightarrow{HOP(OC_2H_5)_2} (C_2H_5O)_2P \!\! -\!\! S\!\! -\!\! P(OC_2H_5)_2 + HCl \end{cases}$$
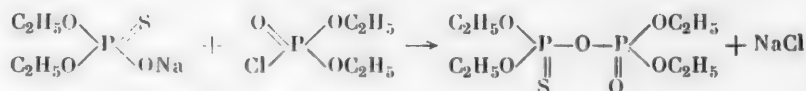
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[*] After this work had been finished and was being prepared for publication, there appeared in print a paper by Michalski and Lenard, who obtained diethyl S-chlorothiophosphate by the action of sulfuryl chloride on diethyl thiophosphate [9].

Unless it isomerizes during distillation, the substance obtained in this way should have a thiol (thioanhydride or thio ester) structure. Isomerization of thiol into thion (containing P = S) type thiopyrophosphates is improbable. It is known that thiol thiophosphates do not isomerize into thion thiophosphates; the process usually occurs in the opposite direction [4].

These conclusions as to the structure of tetraethyl thiopyrophosphate are in agreement with the findings of a previous paper, in which it was shown that sulfenyl chlorides, which resemble diethyl S-chlorothiophosphate in having the functional group S—Cl, react with acid and neutral phosphates to form thio esters of phosphoric acid, i.e., thiol type thiophosphates [3].

There are different views as to the structure of this thiopyrophosphate. The tetraethyl thiopyrophosphate, obtained by the action of hydrogen sulfide on diethyl chlorophosphate and pyridine was assigned a thiol type structure [5]. The same structure was assigned to the tetraethyl thiopyrophosphate obtained by the action of sulfur dichloride on diethyl phosphite [6, 7].

Schrader reckoned that the thiopyrophosphate obtained by the acylation of sodium diethyl thiophosphate with diethyl chlorophosphate (i.e., by a similar method) had a thion type structure [8].

$$\underset{C_2H_5O}{\overset{C_2H_5O}{>}}P\underset{ONa}{\overset{S}{<}} + \underset{Cl}{\overset{O}{>}}P\underset{OC_2H_5}{\overset{OC_2H_5}{<}} \rightarrow \underset{C_2H_5O}{\overset{C_2H_5O}{>}}P\underset{\overset{\|}{S}}{}-O-P\underset{\overset{\|}{O}}{}\underset{OC_2H_5}{\overset{OC_2H_5}{<}} + NaCl$$

In this case, a thiopyrophosphate of a different structure could only be formed by isomerization of the thion type thiopyrophosphate during distillation. A. E. and B. A. Arbuzov suggested the thion structure for tetraethyl thiopyrophosphate obtained by any method [7], on the grounds that thiopyrophosphates obtained by different methods had the same physicochemical constants.

EXPERIMENTAL

Diethyl S-chlorothiophosphate. Working at room temperature, 10.7 g of sulfuryl chloride was added, drop by drop, to 26.7 g of freshly prepared tetraethyl bisthiophosphate. The reaction mixture acquired an orange color. After the addition, the mixture was heated on a water bath, at 50° C, for 15-20 minutes, and then evacuated for half an hour to remove SO_2. The residue was distilled in vacuo. A second distillation gave 15.4 g (48%) of product.

B. p. 90-91° (3.5 mm), d_4^{17} 1.2834, $n^{15}D$ 1.4650.

Literature data [9]: b. p. 61-62° (0.4 mm), d_{25} 1.27031, $n^{25}D$ 1.4672.

Found %: S 15.53; P 15.01; Cl 17.52. $C_4H_{10}O_3SPCl$. Calculated %: S 15.65; P 15.16; Cl 17.36.

The straw-yellow colored liquid, with a smell recalling that of sulfur monochloride, dissolved well in organic solvents; it reacted with water, alcohol and diethylamine with evolution of heat, and liberated iodine quantitatively from an acidified solution of potassium iodide.

Tetraethyl thiopyrophosphate. Diethyl phosphite (2.3 g) was added to 3.4 g of diethyl S-chlorothio-phosphate at − 10° to 0°. The reaction evolved considerable heat. The product was evacuated and then distilled. Yield 2 g (39%).

B. p. 139° (2 mm), $n^{18}D$ 1.4500.

O,O-Diethyl S-chloromethyl thiophosphate. A solution of 6.8 g of diethyl S-chlorothiophosphate in 10 ml of anhydrous ether was cooled in ice and salt, and stirred during the addition of an ethereal solution of diazomethane, prepared by decomposition of 10.3 g of nitrosomethylurea. The color of the solution gradually faded during the reaction and nitrogen bubbles were evolved. The ether was then distilled off on a water bath, and the residue was vacuum distilled. A second distillation gave 2.6 g (36%) of product.

B. p. 113-115° (3.5 mm), d_4^{18} 1.2610, $n^{19}D$ 1.4700.

Found %: S 14.30; P 13.55; Cl 16.25. $C_5H_{12}O_3SPCl$. Calculated %: S 14.64; P 14.19; Cl 16.25.

O,O-Diethyl S-β-chloroethyl thiophosphate. A stream of dry ethylene was passed at room temperature through 7.8 g of diethyl S-chlorothiophosphate until its weight had increased by 0.7 g. Two distillations of the reaction mixture gave 5.9 g (66%) of product.

B. p. 131-132° (4 mm), d^{19}_4 1.2299, $n^{19.5}D$ 1.4750.

Found %: S 13.60; P 12.96; Cl 14.71. $C_6H_{14}O_3SPCl$. Calculated %: S 13.76; P 13.33; Cl 15.27.

The literature data for O,O-diethyl S-β-chloroethyl thiophosphate [3] is: b. p. 135-136° (5 mm), $n^{21}D$ 1.4780.

O,O-Diethyl S-β-chlorocyclohexyl thiophosphate. Water was used to cool 5.3 g of diethyl S-chloro-thiophosphate during the addition of 2.2 g of cyclohexene. The reaction was exothermic; the temperature during the reaction was maintained at 10-20°. Two distillations gave 5.75 g (72%) of product.

B. p. 160-161° (3 mm), or 145-146° (1 mm), d^{18}_4 1.2162, $n^{19}D$ 1.4918.

Found %: S 11.28; P 11.20; Cl 12.33. $C_{10}H_{20}O_3SPCl$. Calculated %: S 11.17; P 10.82; Cl 12.39.

SUMMARY

1. Diethyl S-chlorothiophosphate has been obtained by the action of sulfuryl chloride on tetraethyl bisthiophosphate.

2. It has been shown that diethyl S-chlorothiophosphate reacts in the same way as a sulfenyl chloride with ethylene, cyclohexene, diethyl phosphite and diazomethane.

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REDUCTION OF SULFOXIDES

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In the isolation of sulfides from petroleum distillates in the form of sulfoxides [1] we were confronted with the necessity of finding a single preparative method of regeneration of sulfides from sulfoxides. It is of general interest to find such a method.

The reduction of sulfoxides was first mentioned by A. M. Zaitsev [2], who stated that hydriodic acid and zinc in dilute sulfuric acid reduce diethyl sulfoxide to diethyl sulfide. More recent data on this question amount in general to the fact that sulfoxides are much more easily reduced than sulfones. On determining the structure of disulfoxides this fact was used in choosing between the formulas RSOSOR' and RSSO$_2$R'. Thus, thianthrene was obtained on reduction of 9,10-dioxothianthrene with zinc dust in glacial acetic acid [3]. Fries and Vogt note the extreme ease of reduction of this disulfoxide — it is converted to thianthrene even on treatment with glacial acetic acid containing hydrogen bromide [4]. Thianthrene was formed in the metalation of 9-oxothianthrene by butyllithium; in the reaction of this agent with 9-oxodibenzothiophene the latter also was reduced: after carboxylation, dibenzothiophene and dibenzothiophenecarboxylic acid were isolated [5]. The structure of β-naphthyl disulfoxide was established through reduction of the latter to β-naphthyl disulfide by heating with a mixture of glacial acetic acid, concentrated sodium sulfite solution, and a few drops of hydriodic acid [6]. Heating of di-p-cresyl m-sulfoxide and p-chlorophenyl sulfoxide with zinc dust in glacial acetic acid leads to the corresponding sulfides; when p-chlorophenyl and nitro-p-cresyl sulfoxides are heated in a sealed tube with alcohol saturated with hydrogen chloride, reduction takes place along with partial chlorination of the reaction products [7]. Fichter and Braun electrolytically reduced diphenyl sulfoxide to diphenyl sulfide at a lead cathode [8]. The reduction of diphenyl and p-tolyl phenyl sulfoxides by metallic sodium (on heating in a sealed tube) is accompanied by drastic decomposition of the sulfoxide molecule [9]. On reduction of aryl and alkyl sulfoxides with Raney nickel the sulfoxides are hydrogenated and desulfurized, the corresponding hydrocarbons being formed [10]. The reduction of sulfoxides to sulfides has been used for the determination of sulfoxides by a titanometric method [11].

It should be noted that in most of the above-mentioned works details on experimental conditions are lacking, and yields of reduction products of the sulfoxides are not stated.

Analysis of the literature on the question shows that no general method of reducing sulfoxides of various structures has been developed up to now. The present work is devoted to the solution of this problem. Preliminary experiments in the reduction of dibenzyl sulfoxide with zinc dust showed that this sulfoxide is not reduced in acetic acid; in a mixture of acetic and hydrochloric acids dibenzyl sulfide is formed in low yield. The unsuitability of a number of other methods of reduction, when applied to sulfoxides, is evident from the literature summary given above.

We studied the reduction of sulfoxides by: 1) hydriodic acid and 2) lithium aluminum hydride. Jerchel and co-workers [12] pointed out the possibility of determining dialkyl sulfoxides with long chains by reducing these sulfoxides with potassium iodide in an acid medium. A test of this method showed it to be inexpedient for the quantitative determination of sulfoxides [13]; however, it was found that treatment with hydriodic acid may be used as a preparative method of reduction of sulfoxides to sulfides. When diisoamyl, dibenzyl, and diphenyl sulfoxides and 1-oxo-3-methyl-1-thiindan react with potassium iodide in a hydrochloric acid–acetic acid medium, the corresponding sulfides are formed in satisfactory yields.

The liberation of iodine in the reaction of a sulfoxide with hydriodic acid may serve as a qualitative reaction for sulfoxides. This reaction permits the detection of $1 \cdot 10^{-5}$ g of dibenzyl sulfoxide in a benzene solution of 0.01% concentration. Sulfides and aromatic hydrocarbons do not interfere with the detection of sulfoxides; oxidizing agents capable of liberating iodine from potassium iodide, as well as compounds which readily combine with iodine (phenols, unsaturated hydrocarbons, etc.), do interfere.

In recent years lithium aluminum hydride has come into widespread use in organic chemistry as a reducing agent. Braun [14] cites data on the reduction of diphenyl sulfoxide to diphenyl sulfide by means of lithium aluminum hydride. We found that on reaction with lithium aluminum hydride in ether-benzene solution diisoamyl, dibenzyl, and diphenyl sulfoxides and 1-oxo-3-methyl-1-thiindan are smoothly reduced to the corresponding sulfides.

Notwithstanding the fact that the reduction of sulfoxides by hydriodic acid proceeds more rapidly in general than reduction by lithium aluminum hydride, the latter method is preferable. On treatment with hydriodic acid the reaction products may be iodinated; thus, when dibenzyl sulfoxide is heated with potassium iodide in a hydrochloric acid−acetic acid medium at 100° for 6 hours, a tetraiodo-substituted sulfide is formed. Reduction of sulfoxides by lithium aluminum hydride does not go to completion; however, the unreacted sulfoxide can be reduced by repeating the treatment.

EXPERIMENTAL

I. Reduction of Sulfoxides with Hydriodic Acid

Qualitative reaction for sulfoxides. Ten ml of glacial acetic acid and 2 ml of concentrated hydrochloric acid were mixed; the solution was divided into two parts. To one-half were added 2-3 drops of the sample being tested; the other half served as control. Then about 0.3 g of iodine-free, recrystallized potassium iodide was added simultaneously to both solutions, the latter were shaken, and their colors were compared. In the presence of a sulfoxide an intense, yellow-brown coloration appeared immediately or within 1-2 minutes (depending on the amount of sulfoxide). The control solution developed a pale-yellow color only after 5 minutes.

Reduction of diisoamyl sulfoxide. In the reduction of all sulfoxides investigated, the excess of potassium iodide amounted to 200% of the theoretical amount.

A 3.7 g quantity of diisoamyl sulfoxide was dissolved in 15 ml of 98% acetic acid, 6.8 ml of concentrated hydrochloric acid was added, followed by a solution of 13.3 g of potassium iodide in 7 ml of water, and the mixture was shaken. After about 20 minutes, 10 g of sodium sulfite was added, and the mixture was diluted with water and extracted with ether. The combined ethereal extracts were washed with alkali solution and water, dried with anhydrous magnesium sulfate, and distilled. Diisoamyl sulfide, b. p. 68-69° (3 mm), $n^{21.5}D$ 1.4515, was isolated in 51.0% yield.

According to literature data [15]: b. p. 214-214.8° (754 mm), $n^{20}D$ 1.4520.

Found%: S 18.30. $C_{10}H_{22}S$. Calculated%: S 18.39.

Reduction of dibenzyl sulfoxide. A mixture of 0.5 g of dibenzyl sulfoxide, 25 ml of CH_3COOH, 1 ml of concentrated hydrochloric acid, and 1.44 g of potassium iodide was heated for 1 hour at 100°. The mixture was diluted with water, just decolorized with sulfite, and extracted with benzene. The benzene extracts were combined, washed with soda and water, and dried with anhydrous magnesium sulfate, and the solvent was distilled off. For separation of unreacted sulfoxide the residue was dissolved in 50 ml of ether and filtered. The ether was distilled from the filtrate; the residue was dibenzyl sulfide, m. p. 48-50°; yield 96.5%. A sample, mixed with a known sample of dibenzyl sulfide, melted at 48-49°. According to literature data [16]: m. p. 49-50°.

Reduction of diphenyl sulfoxide. A 6.95 g quantity of diphenyl sulfoxide, 50 ml of acetic acid, 12 ml of concentrated hydrochloric acid, and 23 g of potassium iodide were mixed. After standing for about 12 hours at room temperature the mixture was heated for 6 hours at 100° and left overnight. On the next day it was treated as in the preceding experiment. The benzene extracts were distilled, and diphenyl sulfide, b. p. 126.5° (3 mm), $n^{22.5}D$ 1.6299, was isolated in 77.0% yield.

According to literature data [17]: b. p. 157-158° (16.5 mm), $n^{18.5}$D 1.635.

Found %: S 16.93. $C_{12}H_{10}S$. Calculated %: S 17.18.

Preparation and reduction of 1-oxo-3-methyl-1-thiindan. 1-Oxo-3-methyl-1-thiindan was prepared by oxidation of 3-methyl-1-thiindan with hydrogen peroxide. 3-Methyl-1-thiindan, b. p. 97.5° (6 mm), n^{20}D 1.5965, was synthesized from 1,1-dioxo-3-methylthiindene [18]. A 7.5 g quantity of 3-methyl-1-thiindan in 15 ml of glacial acetic acid was oxidized with 5.23 g of 30% H_2O_2 at 25-30° (ice-water cooling). The mixture was diluted with water to about 100 ml and distilled in the vacuum of a water-jet pump, water being added 3 times; toward the end it was concentrated to a volume of about 10 ml and extracted with chloroform. The extracts were washed with soda and dried with anhydrous calcium chloride. The solvent was driven off (in vacuo toward the end). The residue was 1-oxo-3-methyl-1-thiindan, a viscous, odorless, nearly colorless oil which could not be distilled in vacuo (decomp.); yield (of crude product) 92.6%.

Found %: S 19.49. $C_9H_{10}SO$. Calculated %: S 19.27.

A mixture of 3.7 g of 1-oxo-3-methyl-1-thiindan, 14 ml of CH_3COOH, 6 ml of concentrated hydrochloric acid, and 22.2 g of potassium iodide was heated for 6 hours at 100° (with stirring). After 2 days the mixture was treated as in the reduction of diphenyl sulfide; 3-methyl-1-thiindan, b. p. 96-97° (6.5 mm), n^{22}D 1.5960, was isolated in 62.3% yield.

Found %: S 21.36. $C_9H_{10}S$. Calculated %: S 21.33.

II. Reduction of Sulfoxides by Lithium Aluminum Hydride

Reduction of diisoamyl sulfoxide. In the reduction of all sulfoxides the excess of lithium aluminum hydride amounted to 200% of the theoretical quantity. The concentration of the ethereal lithium aluminum hydride solution was about 0.8 M.

To 48 ml of the ethereal lithium aluminum hydride solution was added a solution of 4.91 g of diisoamyl sulfoxide in 25 ml of anhydrous benzene. The mixture was boiled (with stirring) for 26 hours (b. p. of mixture 48-49°) and then decomposed by water and hydrochloric acid. The organic layer was separated and the water layer extracted twice with benzene; the extracts were combined with the organic layer, dried, and distilled. Diisoamyl sulfide, b. p. 59-60° (1.5 mm), n^{20}D 1.4520, was isolated in 62.6% yield.

Reduction of dibenzyl sulfoxide. To 8.1 ml of the ethereal lithium aluminum hydride solution was added a solution of 1 g of dibenzyl sulfoxide in 45 ml of benzene, and the mixture was boiled for 8 hours. After the usual treatment the mixture was extracted with benzene, the extract dried, and the solvent distilled off. The residue was dibenzyl sulfide; yield (of crude product) 81.7%; after recrystallization from petroleum ether, m. p. 48-49°.

Reduction of diphenyl sulfoxide. To 46.5 ml of the ethereal lithium aluminum hydride solution was added a solution of 5 g of diphenyl sulfoxide in 25 ml of benzene, and the mixture was boiled for 10 hours. After the usual treatment diphenyl sulfide, b. p. 101-102° (0.5 mm), n^{20}D 1.6310, was isolated in 77.2% yield. Found %: S 16.92.

Reduction of 1-oxo-3-methyl-1-thiindan. To 33 ml of the ethereal lithium aluminum hydride solution was added a solution of 2.93 g of 1-oxo-3-methyl-1-thiindan in 15 ml of benzene, and the mixture was boiled for 1 hour, water added, the solvents driven off, and the reaction product then distilled, water being periodically added. The distillate was extracted with benzene and the extracts combined with the driven-off solvents, dried, and distilled in turn. 3-Methyl-1-thiindan, b. p. 119-120° (22 mm), n^{20}D 1.5959, was isolated in 60% yield. Found %: S 21.38.

SUMMARY

1. Two preparative methods for the reduction of sulfoxides of various structures to sulfides have been developed: 1) treatment with lithium aluminum hydride in ether-benzene solution and 2) treatment with potassium iodide in a mixture of acetic and hydrochloric acids.

2. A qualitative reaction for sulfoxides is proposed.

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INVESTIGATION IN THE FIELD OF SYNTHESIS AND TRANSFORMATIONS IN THE DIARYLCARBAMIDE SERIES

IX. SYNTHESIS OF UNSYMMETRICAL DIPHENYLCARBAMIDES CHLORO SUBSTITUTED IN THE NUCLEUS

D. F. Kutepov, A. A. Potashnik, and N. S. Rozanova

Various arylcarbamides are synthesized, as a rule, through the interaction of the corresponding nuclear-substituted arylamines with phosgene. In this case, symmetrical diarylcarbamides are always obtained; i.e., both aryl radicals contain equal amounts of the same substituents in identical positions. An exception is the case where the substituents are introduced directly into the diarylcarbamide molecule, e.g., in the chlorination of diphenylcarbamide. In this case, besides the final product, hexachlorodiphenylcarbamide, the reaction medium is found to contain certain amounts of partially chlorinated products — symmetrical tetrachlorodiphenyl-carbamide and unsymmetrical 2,4,6,2',4'-pentachlorodiphenylcarbamide (I). The former is described in [1]. As regards pentachlorodiphenylcarbamide (I), it has not previously been obtained in pure form. From both the theoretical and practical points of view the study of the properties of this compound is of considerable interest; the synthesis of substances of this type was undertaken in connection with this.

It is generally known that diarylcarbamides also can be prepared from aryl isocyanates and the corresponding arylamines [2, 3]. In this case the reaction proceeds according to the equation

$$ArN{=}CO + Ar'NH_2 \longrightarrow ArNHCONHAr'.$$

In the synthesis of (I) one could begin with 2,4,6-trichlorophenyl isocyanate (II) and dichloroaniline, or with dichlorophenyl isocyanate and trichloroaniline. We chose the first variant.

The question of the relative rate of reaction of (II) with amines containing different numbers of chlorine atoms in the nucleus also was of some interest. In connection with this we used the stated method to synthesize certain other unsymmetrical chloro-substituted diphenylcarbamides, hitherto not described, having the general formula
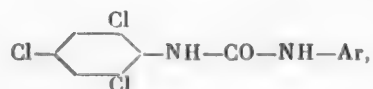
namely, 2,4,6,2',6'-pentachlorodiphenylcarbamide (III), 2,4,6,2',5'-pentachlorodiphenylcarbamide (IV), 2,4,6,4'-tetrachlorodiphenylcarbamide (V), 2,4,6,2',4',5'-hexachlorodiphenylcarbamide (VI), and 2,4,6-trichlorodiphenyl-carbamide (VII).

All these compounds were synthesized through the reaction of (II) with the corresponding chloro-substituted anilines in a dry dichloroethane medium at 20°. The formation and precipitation of the final products took place at various rates. Thus (I) and (VI) began to separate out within 15 minutes and were completely precipitated within 48 hours. (III) and (IV) began to separate out from solution only after 5-7 hours, and the reaction was complete within 70-90 hours. The formation of (V) proceeded very vigorously with evolution of heat and continued for 10-15 minutes in all. Obviously the position and number of chlorine atoms in the amine molecule

has a conside able effect on the rate of reaction of these amines with (II).   4-Chloroaniline proved to be the most reactive.

All the unsymmetrical carbamides prepared by us were colorless, amorphous powders without odor. They were insoluble in water and slightly soluble in organic solvents. In a sealed capillary they melted quite sharply and without decomposition.

EXPERIMENTAL

2,4,6 Trichlorophenyl isocyanate (II). This was prepared under conditions slightly different from those described for the synthesis of 2,4,5-trichlorophenyl isocyanate [2, 3]. Into a reaction vessel, situated in a freezing mixture and provided with thermometer, bubbler, dropping funnel, and outlet tube, was put 55 ml of dry, alcohol-free ethyl acetate; the latter was cooled to 0-5°, and 48 g of phosgene was then condensed in it. At the same time, a solution of 20 g of 2,4,6-trichloroaniline in 100 ml of ethyl acetate was prepared. The trichloroaniline solution was added dropwise to the solution of phosgene in ethyl acetate, with stirring. In this case, the temperature of the reaction mixture rose spontaneously to 20-26° and was maintained at this level during the entire operation. During the addition of the trichloroaniline solution a strong current of phosgene was passed through the reaction mixture. When the addition of the trichloroaniline solution was finished, the mixture was kept at the same temperature and the passage of phosgene continued for 1 hour more; i.e., the time required for nearly complete solution of the precipitate formed. The solution was filtered, the insignificant amount of hexachlorodiphenylcarbamide formed being removed, and the filtrate was evaporated in a vacuum desiccator. The dry residue was quickly recrystallized from petroleum ether or chloroform. The resulting (II) melted at 66-67.5° (according to literature data: 65-66° [4]). The yield was 83%.

No. of substance	Melting point	Formula	Results of analysis (calculated values in parentheses)
(I)	247—249°	$C_{13}H_7ON_2Cl_5$	C 40.88 (40.61); H 2.52 (1.82); N 6.97 (7.28)
(III)	247—249	$C_{13}H_7ON_2Cl_5$	N 7.03 (7.28); Cl 45.01 (46.11)
(IV)	252—254	$C_{13}H_7ON_2Cl_5$	C 40.84 (40.61); H 2.22 (1.82); N 7.18 (7.28)
(V)	245—248	$C_{13}H_6ON_2Cl_4$	C 44.61 (44.60); H 2.46 (2.28); N 7.58 (8.00); Cl 40.74 (40.82)
(VI)	255—258	$C_{13}H_6ON_2Cl_6$	C 37.8 (37.25); H 1.81 (1.43); N 6.59 (6.69)
(VII)	244—246	$C_{13}H_9ON_2Cl_3$	C 49.39 (49.45); H 3.16 (2.85); N 8.32 (8.88)

The melting points (in a sealed capillary) and analytical data of the synthesized diphenylcarbamides are given in the table.

SUMMARY

Unsymmetrical chloro-substituted diphenylcarbamides, not previously described in the literature, have been prepared, and a practically convenient method of synthesizing them in 80-95% yields has been developed.

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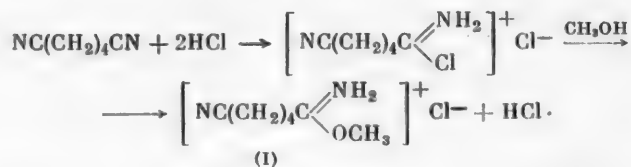# PREPARATION OF IMIDO ETHERS AND ESTERS OF δ-CYANOVALERIC ACID

E. N. Zil'berman and A. E. Kulikova

Today it is almost customary to consider [1-3] that equivalent quantities of nitrile, alcohol, and hydrogen halide are required for the formation of imido ethers and that the reaction takes place in one step according to the equation

$$RCN + R'OH + HCl \longrightarrow RC{\overset{NH \cdot HCl}{\underset{OR'}{\diagup}}}$$
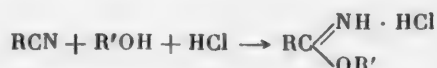
Yields of imido-ether salts in this case are low. Furthermore, they are seldom obtainable in the form of pure compounds [4]. It was recently proposed [5] that imido ethers be hydrolyzed in order to prepare δ-cyano-valeric acid esters, which can be used as intermediates in the production of polyamide resins. However, according to these data, the yields of the esters are not satisfactory. Besides, neither the intermediate, nor the final products are described in the patents [5]. In the preceding work [6] we showed that when 1 mole of adiponitrile reacts with 2 moles of hydrogen chloride, an unstable compound (apparently δ-cyanovalerimidochloride hydrochloride) is formed, which on reaction with an equivalent quantity of water gives a quantitative yield of δ-cyanovalerimido-hydrin hydrochloride (hydrochloride of the lactim form of δ-cyanovaleramide). In the same work we found that in the presence of an insufficient amount of hydrogen chloride and water the stated imidohydrin hydrochloride forms a very stable molecular compound with adiponitrile.

In the light of these data and also on the basis of obscure statements by Houben [4] on the participation of 2 hydrogen chloride molecules in the formation of 1 imido-ether group, we assumed that it would be expedient to carry out the synthesis of imido ethers in two steps, i.e., first to add 2 hydrogen chloride molecules to the nitrile group and then, after a definite period of time, to treat the product with alcohol. In work done by us in this manner adiponitrile, methanol, and hydrogen chloride in an ether, benzene, dioxane, or carbon tetrachloride medium gave a theoretical yield of solid δ-cyanovalerimido methyl ether hydrochloride (I):

$$NC(CH_2)_4CN + 2HCl \longrightarrow \left[NC(CH_2)_4C{\overset{NH_2}{\underset{Cl}{\diagup}}} \right]^+ Cl^- \xrightarrow{CH_3OH}$$

$$\longrightarrow \left[NC(CH_2)_4C{\overset{NH_2}{\underset{OCH_3}{\diagup}}} \right]^+ Cl^- + HCl \cdot$$

(I)

From the same components, taken in the molar ratio 1:1:0.5, a molecular compound (II) of the hydrochloride (I) and adiponitrile was obtained.

$$\left[NC(CH_2)_4C{\overset{NH_2}{\underset{OCH_3}{\diagup}}} \cdot NC(CH_2)_4CN \right]^+ Cl^-$$

(II)
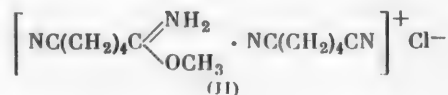
Similar molecular compounds are not described in the literature. When the reaction was carried out under the conditions given in [3, 5], i.e., with a molar ratio of 1:1:1 among the components and with hydrogen

chloride passing into the ether or benzene solution of adiponitrile and methanol, both the hydrochloride (I) and the molecular compound (II) were formed. On hydrolysis of the product of this reaction a mixture of methyl δ-cyanovalerate (60% of the theoretical, reckoned on adiponitrile) and adiponitrile was obtained. We were unable to separate methyl δ-cyanovalerate (III) from the given mixture by fractional distillation in a 3-5 mm vacuum, since it was unstable under the distillation conditions and evidently behaved similarly to δ-cyanovaleric acid [7]; i.e., it underwent rearrangement to adiponitrile and dimethyl adipate. The absence of any description of the methyl ester (III) in the patents [5] is explained by this. On hydrolysis of the hydrochloride (I) synthesized by us, we obtained the methyl ester (III), which did not require further purification (see table).

δ-Cyanovaleric Acid Esters $NC(CH_2)_4C{<}^{O}_{OR}$

| Compound | R | Yield (in %) | Boiling point (pressure in mm) | Nitrogen content (in %) | | n_D^{20} | d_4^{20} | MR_D | |
				calc.	found			calc.	found
(III)	CH_3	93.5	120—122° (10) *	9.92	9.75	1.4321 *	1.0362	35.99	35.30
(IV)	CH_3CH_2	96.5	140 (16) **	9.03	9.17	1.4359	1.0034	40.62	40.53
(V)	$CH_3CH_2CH_2$	96.7	156—158 (5)	8.28	8.21	1.4352	0.9798	45.23	45.20
(VI)	$CH_3(CH_2)_3$	98.3	164 (5)	7.65	7.54	1.4372	0.9647	49.85	49.71
(VII)	$CH_3(CH_2)_4$	99.0	152 (3)	7.10	7.31	1.4389	0.9536	54.47	54.37
(VIII)	$CH_3(CH_2)_5$	99.1		6.63	6.21	1.4402	0.9392	59.09	58.63

* According to literature data: b. p. 119-120° (9 mm), $n^{15}D$ 1.4315 [8].
** According to literature data: b. p. 135° (15 mm) [8].

δ-Cyanovalerimido ethyl, propyl, butyl, amyl, and hexyl ethers proved to be compounds difficult to crystallize. Therefore, they were not isolated but were hydrolyzed directly in the reaction mixture, the corresponding δ-cyanovaleric acid esters (compounds (IV) - (VIII), see table) being formed. The near-quantitative formation of esters (IV) - (VIII) from adiponitrile confirms the efficacy of the method of imido-ether preparation, used in the present work.

EXPERIMENTAL

Preparation of δ-cyanovalerimido methyl ether hydrochloride (I) and methyl δ-cyanovalerate (III). Into a heterogeneous mixture of 108 g of adiponitrile and 200 ml of dry ether, cooled to 0° and stirred, 73 g of dry hydrogen chloride was passed. The mixture was kept in the cold for 4 hours, after which 32 g of dry methanol was added. The mixture very quickly stratified, after which the lower layer crystallized. After 20 hours the white crystals, which had separated, were filtered out, washed with dry ether, and dried in a desiccator over $CaCl_2$, 176.5 g (100%) of (I) being obtained. This strongly hygroscopic substance was kept in an atmosphere of dry air for a long time without appreciable decomposition; it was soluble in water, glacial acetic acid, and alcohol and insoluble in ether and benzene; it softened at 98° and had m. p. 165-176° (decomp.) (from a mixture of glacial acetic acid and ether).

Found %: Cl 20.1; N (total) 15.80; N (amide) 7.9. $C_7H_{13}ON_2Cl$. Calculated %: Cl 20.1; N (total) 15.86; N (amide) 7.9.

20 g of (I) was dissolved in 20 ml of water. After 2-3 hours at 30-40° hydrolysis was complete and the upper layer of the mixture was drawn off. The water layer was extracted several times with ether. After the upper layer and ethereal extracts were dried with calcium chloride, the ether was removed and 14.9 g (93.5%) of methyl δ-cyanovalerate was obtained (see table).

Preparation of the molecular compound of δ-cyanovalerimido methyl ether hydrochloride and adiponitrile (II). (II) was synthesized in the same way as (I). From 21.6 g of adiponitrile, 7.3 g of hydrogen chloride, and 3.2 g of dry methanol there was obtained 25.6 g (90%) of (II), m. p. 90-95°.

Found %: Cl 12.41; N 19.62. $C_{13}H_{21}ON_4Cl$. Calculated %: Cl 12.47; N 19.68.

This white, powdered, strongly hygroscopic substance was kept in an atmosphere of dry air without appreciable decomposition; it was soluble in water and alcohol. On thorough rinsing of 10 g of (II) with dry benzene there was obtained 3.8 g of adiponitrile and 6.2 g of (I), which, according to its analysis, was identical with the substance described above.

Preparation of butyl δ-cyanovalerate (VI). Into a heterogeneous mixture of 21.6 g of adiponitrile and 40 ml of dry ether was passed 14.6 g of dry hydrogen chloride at 0°, and the mixture was left to stand in the refrigerator at 0-5°. After 4 hours, 14.8 g of dry butanol was added to the mixture. Within 40 hours the mixture stratified and the lower layer solidified. The excess hydrogen chloride and ether were removed in vacuo. The remaining viscous, slightly yellowish mass was dissolved in 50 ml of water and heated for 3 hours at 50-60°. The mixture stratified. The upper layer was drawn off and the water layer extracted with ether. After drying with calcium chloride the product was fractionally distilled. There was obtained 36 g (98.3%) of butyl δ-cyanovalerate (see table).

SUMMARY

1. It has been shown that in order to prepare δ-cyanovalerimido ether hydrochlorides in high yield adiponitrile, hydrogen chloride, and the alcohol must be taken in the molar ratio 1:2:1.

2. A molecular compound of a δ-cyanovalerimido ether hydrochloride and adiponitrile has been obtained.

3. Six δ-cyanovaleric acid esters have been synthesized.

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* Russian translation.
** Original Russian pagination. See C. B. Translation.

ABSORPTION SPECTRA AND MOLECULAR STRUCTURE

VI. CHROMATICITY OF 9-FORMYLACRIDINE ARYLHYDRAZONE HYDROCHLORIDES CONTAINING CONDENSED-RING AND HETEROCYCLIC RADICALS

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It was noted earlier [1] that the chromaticity, i.e., the position of the principal absorption maximum and the intensity of absorption of organic compounds depends on the number of interacting π-electrons and the total displacement of electron density in the molecule. The more interacting π-electrons there are in the molecule and the greater the total displacement of electron density therein is, other conditions being equal, the deeper the color of the compound is. These regularities remain valid even for conjugated systems interrupted by an imino group [2] and, in particular, for the 9-formylacridine arylhydrazone hydrochlorides which were investigated in the present work. Introduction of condensed rings and heterocyclic radicals (Figs. 1-5, table) into the system in place of the phenyl radical ($R = C_6H_5$) made it possible to confirm once more the validity of the thesis stated above. Thus the deepening of color on increase of the number of π-electrons entering into a single electron cloud in such a system can be followed as the phenyl radical of 9-formylacridine phenylhydrazone hydrochloride ($R = C_6H_5$, λ_{max} 562 mμ) is replaced by naphthyl ($R = C_{10}H_7$, λ_{max} 595 mμ, for the α- and 592 mμ for the β-derivative). Here the displacement of the principal maximum amounts to $+33$ and $+30$ mμ, respectively, toward the infrared part of the spectrum (Figs. 1 and 2, table).

Introduction of the acenaphthenyl ($R = C_{12}H_9$, λ_{max} 610 mμ, Fig. 1) and especially the carbazolyl radical ($R = C_{12}H_8N$, λ_{max} 660 mμ, Fig. 2) in place of naphthyl in the molecules of the compounds investigated, also is accompanied by a pronounced bathochromic shift ($+98$ and $+108$ mμ, respectively) not on account of the increase in the total number of interacting π-electrons, but because of the electrodotic properties of the radicals, owing to which the total displacement of the electron density in the direction from radical R to the acridinium nitrogen ($H-N\!\!<$, Figs. 1 and 2, table) is increased.
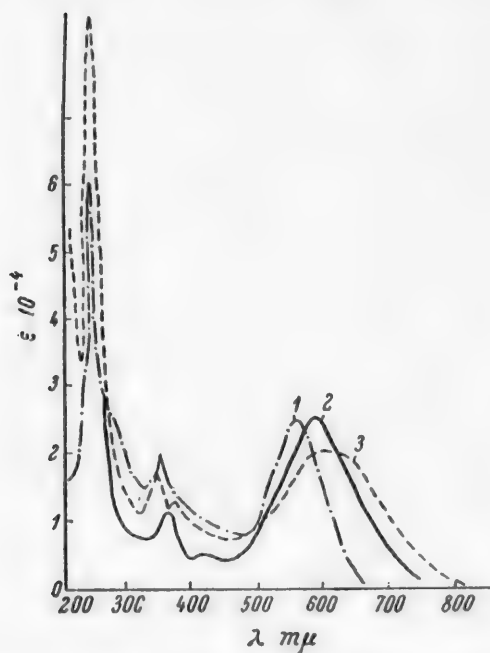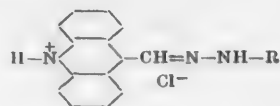

Fig. 1. Absorption spectra in 0.2 N alcoholic hydrochloric acid solution. 1) 9-Formylacridine phenylhydrazone (I); 2) 9-formylacridine 1'-naphthylhydrazone (II); 3) 9-formylacridine 5'-acenaphthenylhydrazone (IV).

Principal Absorption Maxima of 9-Formylacridine Arylhydrazone Hydrochlorides

(in 0.2 N alcoholic hydrochloric acid solution)*

No. of substance	R	Absorption maxima						Shift of the maximum (in mμ) relative to (I)
		λ_1 mμ	$\varepsilon \cdot 10^{-4}$	λ_2 mμ	$\varepsilon \cdot 10^{-4}$	λ_3 mμ	$\varepsilon \cdot 10^{-4}$	
I	C_6H_5	254	6.0	364	1.1	562	2.5	—
II	$\alpha\text{-}C_{10}H_7$	256	—	363	1.76	595	2.56	33
III	$\beta\text{-}C_{10}H_7$	256	3.7	367	0.76	592	2.0	30
IV	[structure H$_5$C—CH$_2$]	258	8.46	355	2.0	610	2.04	48
V	[structure: —N$^+$(H)Cl$^-$ =CH, NH]	258	4.8	360	1.2	550	1.26	−12
VI	[structure: —CH=C—C—CH$_3$, O=C N O]	258	4.44	360	1.18	540	1.58	−22
VII	[anthraquinonyl structure]	250	5.36	365	0.98	522	1.8	−40
VIII	[anthraquinonyl structure]	250	4.32	360	0.92	520	1.32	−42
IX	[carbazolyl structure, NH]	257	3.36	354	1.6	660	1.44	98

* Hydrochloric acid (d 1.19) diluted with 96% alcohol.

Replacement of the phenyl radical by anthraquinonyl ($R=C_{14}H_7O_2$, λ_{max} 522 mμ for the α- and 520 mμ for the β-derivative), benzimidazolyl ($R=C_7H_5N_2$, λ_{max} 550 mμ), and other radicals with stronger electrophilic properties is accompanied, owing to the decrease in the total displacement of electron density in the molecule, by a shift of the principal absorption band maximum (amounting to −40, −42, −12, and −22 mμ) toward the violet end of the spectrum, i.e., a heightening of the color (Figs. 3-5, table). The number of interacting π-electrons in these systems is not diminished but is increased. In this case, the bathochromic effect of the increase in the number of interacting π-electrons is overbalanced by the hypsochromic effect of the radical.
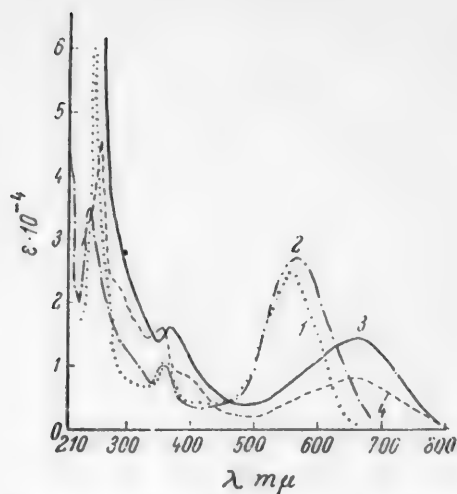
Fig. 2. Absorption spectra in 0.2 N alcoholic hydrochloric acid solution. 1) 9-Formyl-acridine phenylhydrazone (I); 2) 9-formyl-acridine 2'-naphthylhydrazone (III); 3) 9-formylacridine 3'-carbazolylhydrazone (IX); 4) 9-formylacridine 4'-(p-phenyl-amino)-phenylhydrazone.
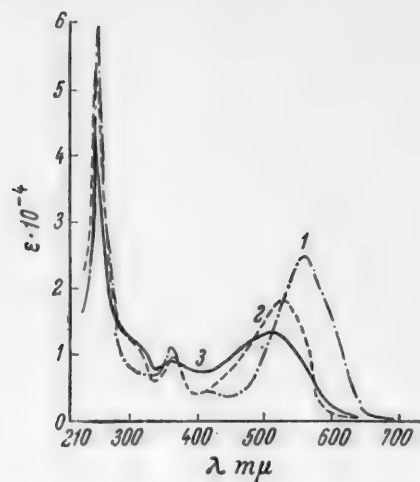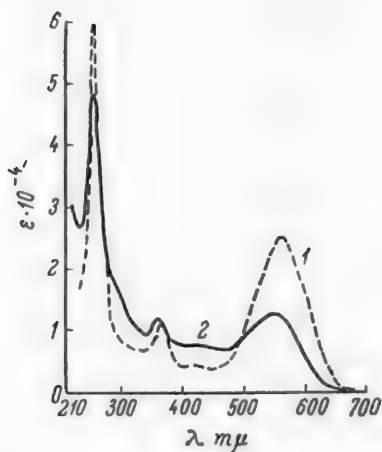

Fig. 3. Absorption spectra in 0.2 N alcoholic hydrochloric acid solution. 1) 9-Formylacridine phenylhydrazone (I); 2) 9-formylacridine 1'-anthra-quinonylhydrazone (VII); 3) 9-formyl-acridine 2'-anthraquinonylhydrazone (VIII).

Fig. 4. Absorption spectra of alcoholic hydrochloric acid solutions. 1) 9-Formylacridine phenylhydrazone (I); 2) 9-formylacridine 5'-benzimidazolyl-hydrazone (V).
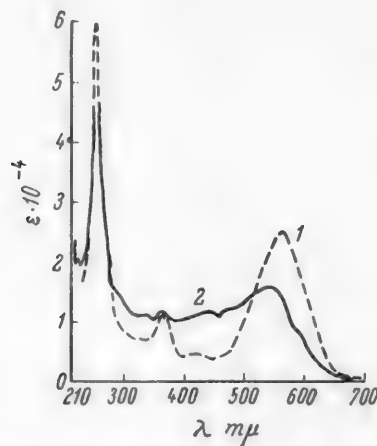

Fig. 5. Absorption spectra of alcoholic hydrochloric acid solutions. 1) 9-Formylacridine phenylhydrazone (I); 2) hydrazone from 9-formylacridine and p-hydrazylbenzylidenemethyl-isoxazolone (VI).

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The given experimental data show that the main role in the chromaticity of organic compounds is played not by the increase in the number of interacting π-electrons, but by the total displacement of electron density in the molecule.

The structures of 9-formylacridine arylhydrazones and their salts were proved earlier by A. E. Porai-Koshits and one of us [3, 4] through countersynthesis by the method of azo-coupling of 9-methylacridine with diazonium salts and by treatment of 9-formylacridine with the corresponding arylhydrazines, and also by studying the properties of their N- and C-alkyl derivatives, determining the elementary composition and analyzing the spectral curves.

The dyes obtained in the present work were purified by recrystallization from organic solvents and by reprecipitation from the latter with water until the principal absorption maximum, form of the spectral curve, and melting point were constant. Their structure was confirmed by the similarity of the spectral curves to those of 9-formylacridine phenylhydrazone, investigated earlier in detail, and by elementary analysis for nitrogen.

EXPERIMENTAL

9-Formylacridine phenylhydrazone (I) and 9-formylacridine α- and β-naphthylhydrazones (II, III) were described earlier [5].

9-Formylacridine 5'-acenaphthenylhydrazone (IV). A 1.1 g quantity of 5-aminoacenaphthene, m. p. 108°, was mixed with 4 ml of water. To the suspension was added 4.5 ml of 37% hydrochloric acid at 20°. The solution was cooled to − 5°, and at that temperature 0.45 g of sodium nitrite, dissolved in 2 ml of water, was added during 10 minutes. After standing for 1 hour the diazonium salt solution was filtered and was added to a solution of 1.3 g of 9-methylacridine (m. p. 110°) and 8 g of crystalline sodium acetate in 30 ml of glacial acetic acid during 1 hour. After standing for 24 hours the yellow-green solution had turned into a dark-green, crystalline mass. The solid matter was filtered out, washed with dilute acetic acid and water, and then recrystallized several times from dilute acetic acid, treated with ammonia, and washed with water until the melting point and the principal absorption maximum in alcoholic hydrochloric acid were constant. Yield 0.7 g (30%). A dark-brown product with m. p. 187°, which readily dissolved in alcoholic hydrochloric acid solution or glacial acetic acid to give a greenish-blue solution, in aqueous-alcoholic sodium hydroxide to give a brown one, in alcohol to give a yellow one, and in alcoholic sodium hydroxide to give a yellow-green one. The maximum of the principal absorption band in alcohol was at 470 mμ, in 0.2 N alcoholic hydrochloric acid solution, at 610 mμ, and in glacial acetic acid at 610 mμ.

Found %: N 11.3. $C_{26}H_{19}N_3$. Calculated %: N 11.3.

9-Formylacridine 5'-benzimidazolylhydrazone (V) was prepared according to directions similar to those given above. A 2.1 g quantity of 5-aminobenzimidazole hydrochloride (decomp. 315-317°) was dissolved in 8 ml of water and 5 ml of 37% hydrochloric acid. The solution was cooled to − 3°, and at this temperature 0.7 g of sodium nitrite in 3.5 ml of water was added during 10 minutes. After standing for 1 hour the solution was filtered and was added to a solution of 2.0 g of 9-methylacridine (m. p. 110°) and 16 g of crystalline sodium acetate in 40 ml of glacial acetic acid during 1 hour. After 24 hours the yellow-green solution had become violet-red. After treatment of the latter with ammonia a yellowish-brown precipitate formed. The latter was filtered out, washed with water, and dried at 50-60°. Yield 2.3 g (68%). The dye base was reprecipitated from hydrochloric acid solutions with ammonia. A yellowish-brown product with m. p. 251°, readily soluble in alcohol, ether, aqueous-alcoholic sodium hydroxide, glacial acetic acid, and hydrochloric acid.

Found %: N 20.9. $C_{21}H_{15}N_5$. Calculated %: N 20.8.

9-Formylacridine 5'-benzimidazolylhydrazone base was dissolved in the minimum quantity of alcohol. The alcoholic solution was saturated with dry hydrogen chloride and poured into a large amount of dry ether. 9-Formylacridine 5'-benzimidazolylhydrazone dihydrochloride separated out in the form of a crimson, nearly black powder decomposing at 246-248°.

Found %: N 16.9. $C_{21}H_{15}N_5 \cdot 2HCl$. Calculated %: N 17.1.

9-Formylacridine 1'-anthraquinonylhydrazone (VII). This was synthesized similarly to the preceding product. The starting material consisted of 2.2 g of α-aminoanthraquinone, m. p. 241°, dissolved in 8 ml of

water, and 8 ml of 37% hydrochloric acid. The sodium nitrite was added during 30 minutes. During the diazotization, the temperature was kept between − 10 and − 5°. The diazonium salt solution was added to the solution of the azo-coupling component during 90 minutes. On coupling with 2 g of 9-methylacridine (m. p. 110°) the color of the reaction mass changed from yellow-green to violet-red. After standing for 24 hours the solid matter was filtered out and washed with dilute acetic acid, water, ammonia, and again water. The product was purified by crystallization from a mixture of alcohol and pyridine until the melting point and the principal absorption maximum in 0.2 N alcoholic hydrochloric acid solution were constant. Yield 1.4 g (32%). The product was dried at 50-60°. M. p. 232°, λ_{max} 448 mμ in alcohol, 522 mμ in 0.2 N alcoholic hydrochloric acid solution, and 520 mμ in glacial acetic acid.

Found %: N 10.1. $C_{29}H_{17}O_2N_3$. Calculated %: N 9.9.

The base was brown and the hydrochloride was brownish-black. The solution of the base in aqueous-alcoholic sodium hydroxide was brown, that in alcohol yellow, that in alcoholic sodium hydroxide brown, that in concentrated sulfuric acid brown, and those in glacial acetic and 0.2 N hydrochloric acids red.

9-Formylacridine 3'-carbazolylhydrazone (IX) was prepared under the conditions described above. From 1.82 g of 3-aminocarbazole, m. p. 254°, and 2 g of 9-methylacridine, m. p. 110°, 1.2 g (31%) of dye was obtained. The diazotization temperature was − 3°. The diazonium salt solution was added to the solution of the azo-coupling component during 2 hours. The coupling time was 24 hours. On coupling, the color of the solution changed from yellowish-green to dark-green. The dye was precipitated from the acetic acid solution on partial neutralization of the latter with ammonia. The precipitate was washed with dilute acetic acid and water. The product was purified by crystallization from dilute acetic acid and reprecipitation from acetic acid solution by ammonia to a constant m. p. of 242° and a constant absorption maximum (567 mμ in 0.2 N alcoholic hydrochloric acid, 570 mμ in glacial acetic acid).

Found %: N 14.9. $C_{26}H_{18}N_4$. Calculated %: N 14.5.

The base was brown; its solution in alcoholic sodium hydroxide was red and that in glacial acetic acid green. It imparted a green color to natural silk. The hydrochloride was black.

Hydrazone from 9-formylacridine and p-hydrazylbenzylidenemethylisoxazolone (VI). The synthesis was carried out according to the preceding directions. From 2 g of p-aminobenzylidenemethylisoxazolone (m. p. 198°) and 2 g of 9-methylacridine (m. p. 110°), 2.1 g (52%) of the dye was obtained. The dye was isolated through precipitation from acetic acid solution by water. It was purified by recrystallization from dilute acetic acid. The purified product was converted to the base by treatment with ammonia. The yellow base melted at 218°. The principal absorption maximum in 0.2 N alcoholic hydrochloric acid was at 540 mμ.

Found %: N 14.1. $C_{25}H_{18}O_2N_4$. Calculated %: N 13.8.

The solution of the base in aqueous-alcoholic sodium hydroxide was yellow, that in alcohol was yellow, that in alcoholic sodium hydroxide green, that in concentrated sulfuric acid dark-brown, and that in glacial acetic acid red.

9-Formylacridine 2'-anthraquinonylhydrazone (VIII). A 2.2 g quantity of 2-aminoanthraquinone (m. p. 302°) was dissolved with heating in 6 ml of 95% sulfuric acid. The solution was then cooled to 0°, and 15 ml of phosphoric acid (d 1.7) and some nitrosylsulfuric acid (0.7 g of sodium nitrite in 8 ml of 95% sulfuric acid) were added. After standing for 24 hours, the solution was slowly poured into 50 g of ice at − 5 to − 6° and the reaction mass neutralized by adding 90 g of sodium acetate, with strong external cooling. The resulting diazonium salt −mineral salt solution was added during 1 hour to a solution of 2.0 g of 9-methylacridine in 30 ml of glacial acetic acid. The reaction mixture gradually changed from yellowish-green to dark-red. After standing for 24 hours, the dye was filtered out and thoroughly washed with dilute acetic acid and water to remove mineral salts and excess 9-methylacridine, and then treated with ammonia, washed with water, and purified by reprecipitation from acetic acid. The brown product melted above 260°, and its principal absorption maximum in 0.2 N alcoholic hydrochloric acid solution was at 520 mμ.

Found %: N 10.2. $C_{29}H_{17}O_2N_3$. Calculated %: N 9.9.

Solutions of the base in aqueous-alcoholic sodium hydroxide, alcoholic sodium hydroxide, and sulfuric acid were brown, its solution in alcohol yellow, and that in glacial acetic acid red. The hydrochloride was brownish-black.

The spectral measurements were performed with a Type SF-1 photoelectric spectrophotometer in the wavelength range from 210 to 800 mμ at 1 mμ intervals. A 0.2 N alcoholic hydrochloric acid solution was used as solvent. The substances were purified before measurement, and their purity was checked by melting point, analysis for nitrogen, and constancy of the long-wave absorption maximum (see table). For the measurements identical concentrations by weight (0.01 mg/ml) were taken, and these were then converted to molar concentrations. Freshly prepared solutions were used in the spectral analyses.

SUMMARY

1. For the case of 9-formylacridine phenyl- and naphthylhydrazone hydrochlorides it was shown that an increase in the number of interacting π-electrons in conjugated systems, interrupted by an imino group is accompanied, just as in ordinary conjugated systems, by deepening of the color.

2. For the case of 9-formylacridine phenyl-, naphthyl-, acenaphthenyl-, and carbazolylhydrazone hydrochlorides it was shown that an increase in the total displacement of electron density from radical R toward the acridinium nitrogen $(H-\underset{+}{N}\leqslant)$ is accompanied by additional deepening of the color. In the case of

9-formylacridine phenyl-, benzimidazolyl-, anthraquinonyl-, and other hydrazone hydrochlorides it was shown that the bathochromic effect of an increase in the number of interacting π-electrons may be overbalanced by the hypsochromic effect of an electrophilic radical on account of the decrease in the total displacement of electron density in the molecule in the given case from the radical toward the acridinium nitrogen.

3. Changes in the structure of the radical attached to the imino group in acid salts of 9-formylacridine hydrazones have little effect on the general outline of the curve, the position of the short-wave maximum, or the relative distribution of intensity of the absorption bands.

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[4] A. A. Kharkharov, Leningrad State University Herald, 4, 145 (1957); 22, 169 (1957).

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* Original Russian pagination. See C. B. Translation.

N-ALKYL DERIVATIVES OF NAPHTHALIMIDE AND HALONAPHTHALIMIDES

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Certain N-alkyl derivatives of naphthalimide are described in the literature. Thus, G. Jaubert[*] prepared N-methylnaphthalimide by heating a mixture of potassium naphthalimide and methyl iodide in sealed tubes at 150°. He obtained this same product by heating naphthalic anhydride with a 10% methylamine solution at 100° for 3 hours. Ethylnaphthalimide, m. p. 148°, was similarly obtained.

In studying the properties of naphthalimide and its halo derivatives, we alkylated them. This was done through the reaction of potassium naphthalimide with the corresponding alkyl bromides in sealed tubes at 150°. In this case, it was found that potassium naphthalimide enters into the alkylation reaction more easily than its halo derivatives.

We prepared the potassium naphthalimide required for the synthesis of alkyl derivatives of naphthalimide both in anhydrous alcohol and in aqueous alkali solution. In order to verify the identity of the products obtained, we alkylated the latter; in this case, the alkyl derivatives proved identical.

EXPERIMENTAL

Potassium naphthalimide. A 19.7 g quantity of naphthalimide was dissolved in 450 ml of boiling 5% potassium hydroxide, the solution cooled, and 50 ml of 30% potassium hydroxide added. The crystals which separated were filtered out, well pressed out, washed with alcohol, and dried at 100-105°. There was isolated 21 g (90%) of potassium naphthalimide.

Potassium 4-chloronaphthalimide. A 23.1 g quantity of 4-chloronaphthalimide was put into a beaker, 200 ml of 5% potassium hydroxide solution added, and the mixture boiled for 20 minutes. The crystalline mass obtained was cooled, filtered, washed with alcohol, and dried at 100-105°. There was isolated 26 g (96.4%) of potassium 4-chloronaphthalimide.

Potassium 4-bromonaphthalimide was prepared similarly to the preceding. Yield nearly quantitative.

N-Ethylnaphthalimide (I). Into a hard-glass test tube were put 2.35 g of potassium naphthalimide and 1 ml of ethyl bromide; the test tube was then sealed off and heated at 150° for 8 hours. The reaction product obtained was boiled in 10 ml of 5% potassium hydroxide solution in order to remove unreacted naphthalimide. The mixture was cooled and the product filtered out, washed with water, and dried. There was isolated 1.4 g (62%), m. p. 155-156°. The substance crystallized well from alcohol, in the form of colorless needles with m. p. 157°. Jaubert gives m. p. 148°; presumably he did not obtain pure N-ethylnaphthalimide, since the unreacted naphthalimide cannot be completely removed by crystallization.

N-Propyl- (IV), N-butyl- (VII), N-amyl- (X), and N-hexyl- (XIII) naphthalimides were prepared similarly to the preceding. Their properties and analytical data are given in the table.

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[*] G. Jaubert, Ber. 28, 360 (1895).

N-Ethyl-4-chloronaphthalimide (II). A 2.7 g quantity of potassium 4-chloronaphthalimide and 1 ml of ethyl bromide were put into a hard-glass test tube, which was then sealed off and heated at 150° for 14 hours. The product obtained was treated with 10 ml of ether and filtered. The unreacted potassium 4-chloronaphthalimide remained on the filter. The filtrate was evaporated and the residue dissolved in 15 ml of alcohol, 0.3 to 0.4 g of activated charcoal was added, and the mixture was boiled for 30 minutes and filtered. The solution was evaporated to a 3-4 ml volume and left to crystallize.

There was isolated 0.5 g (19%) of (II).

N-Alkyl Derivatives of Naphthalimide and Halonaphthalimides
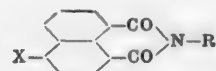
No. of substance	Meaning of R	Meaning of X	Yield (in %)	External crystal form	Melting point	Analysis for N (in %) found	calc.
(I)	C_2H_5	H	61	Needles	157°	6.47, 6.14	6.21
(II)	C_2H_5	Cl	18	Fine, umbrella-shaped needles	165—166	5.27, 5.44	5.39
(III)	C_2H_5	Br	19	Same	163	4.98, 4.75	4.60
(IV)	C_3H_7	H	96	Needles	160	5.98, 5.73	5.85
(V)	C_3H_7	Cl	91	Fine needles	142.5—143	5.24, 5.34	5.11
(VI)	C_3H_7	Br	89	Same	126	4.20, 4.28	4.40
(VII)	C_4H_9	H	89	Needles	98—99	5.75, 5.55	5.53
(VIII)	C_4H_9	Cl	66	Same	93	4.67, 4.72	4.87
(IX)	C_4H_9	Br	98	Same	105	3.98, 4.28	4.21
(X)	C_5H_{11}	H	90	Leaflets	87.5—88.5	5.55, 5.39	5.24
(XI)	C_5H_{11}	Cl	76	Needles	74—75	4.82, 4.74	4.64
(XII)	C_5H_{11}	Br	68	Lamellae	90.5—91.5	4.31, 4.36	4.04
(XIII)	C_6H_{13}	H	75	Needles	72—73	4.99, 5.15	4.98
(XIV)	C_6H_{13}	Cl	64	Lamellae	65	4.48, 4.30	4.43
(XV)	C_6H_{13}	Br	47	Fine, needles, grouped into nodules	62	3.73, 3.70	3.88

N-Propyl- (V), N-butyl- (VIII), N-amyl- (XI), and N-hexyl- (XIV) 4-chloronaphthalimides, and also N-ethyl- (III), N-propyl- (VI), N-butyl- (IX), N-amyl- (XII), and N-hexyl- (XV) 4-bromonaphthalimides were prepared similarly to the preceding. The properties and analyses of the compounds obtained are given in the table. All products were crystallized from alcohol.

SUMMARY

1. It has been established that potassium naphthalimide and its halo derivatives can be prepared in good yields not in anhydrous alcohol but in an aqueous medium on treatment with potassium hydroxide.

2. Halo derivatives of potassium naphthalimide are alkylated with more difficulty than potassium naphthalimide itself.

3. A number of compounds not described in the literature have been prepared.

# INVESTIGATIONS IN THE FIELD OF QUINOLINE AND ITS DERIVATIVES

XXIII. N-ARYLLEPIDINIUM SALTS

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N-Aryl quaternary salts of quinoline and its derivatives hitherto have been relatively little studied. Brucker [1] synthesized N-aryl quaternary salts of quinoline, quinaldine, and lepidine from diphenylamine and α,β-unsaturated aldehydes and ketones. Then, G. T. Pilyugin extended the Doebner-Miller reaction to secondary aromatic amines for the first time. As a result of this investigation, a number of N-aryl quaternary salts of bases of the quinoline series, having a methyl group in position 2, were prepared [2, 3]. Later Pilyugin improved this synthesis, replacing acetaldehyde or paraldehyde with vinyl ethers [4]. Recently, Pilyugin [5] prepared lepidinium iodophenoxide by carrying out the Baeyer reaction in a dioxane medium in sealed tubes.

We found that diarylamines may be co-condensed with formaldehyde and ketones without the use of pressure by the method developed by us earlier [6], N-aryllepidinium salts being formed. The reaction mechanism is as follows:
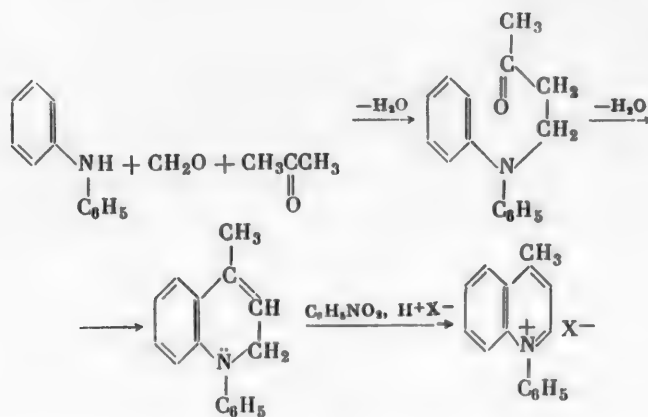
It is remarkable that addition of nitrobenzene to the reaction medium increases the yield of quaternary salts 4- to 5-fold.*

EXPERIMENTAL**

1. N-Phenyllepidinium perchlorate. 1) Into a round-bottom flask, provided with a reflux condenser and two burets, were put 20 ml of acetone, 30 ml of alcohol, 25 ml of nitrobenzene, and 15 ml of concentrated

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* Cases of the successful use of nitrobenzene as an oxidizing agent in the Baeyer reaction are unknown.

** Done in the organic chemistry laboratory of Rostov-on-Don University.

hydrochloric acid. Into one of the burets was put a solution of 10 g of diphenylamine in 10 ml of acetone; into the other, a solution of 1.8 g of paraformaldehyde in 20 ml of alcohol. The mixture in the flask was heated to boiling, and 1 ml portions of the diphenylamine and paraformaldehyde solutions were alternately added to it every 7.5 minutes. When the addition of the solutions was finished, the reaction mixture was boiled for 1 hour. The contents of the flask were then diluted with 150 ml of distilled water and steam distilled; in this case the alcohol, acetone, and nitrobenzene were driven from the reaction mass. The N-phenyllepidinium chloride solution remaining in the flask was decanted from the tar, boiled with activated charcoal, filtered to remove the latter, and evaporated to a 40-50 ml volume. On treatment of the aqueous N-phenyllepidinium chloride solution with 5% perchloric acid, N-phenyllepidinium perchlorate precipitated. The quaternary-salt crystals were filtered out, washed with water, and recrystallized from water. There was obtained 2.9 g (15%) of light-yellow crystals with m. p. 173-174°.

Found %: N 4.17; Cl 11.11. $C_{16}H_{14}O_4NCl$. Calculated %: N 4.38; Cl 11.09.

2) This experiment was performed like the first, but nitrobenzene was not used in the reaction. Yield of product with m. p. 173°, 0.58 g (3%). A mixture test with the product obtained in the preceding experiment gave no melting-point depression.

II. N-Phenyl-3-methyllepidinium perchlorate.* Into a round-bottom flask provided with a reflux condenser and two burets were put 10 ml of methyl ethyl ketone, 30 ml of alcohol, and 20 ml of concentrated hydrochloric acid. A solution of 15 g of diphenylamine in a mixture of 10 ml of methyl ethyl ketone and 10 ml of alcohol was put into one of the burets, and a solution of 2.7 g of paraformaldehyde in 32 ml of alcohol was put into the other. The reaction mixture was heated to boiling, and 1 ml portions of the diphenylamine and paraformaldehyde solutions were added to it every 5 minutes. When the contents of the burets had been added, the reaction mixture was boiled for 1 hour. The reaction product was isolated and purified just as in the preceding experiments. There was obtained 2.45 g (8%) of crystals with m. p. 168°. N-Phenyl-3-methyllepidinium perchlorate is reported for the first time.

Found %: N 3.98; Cl 10.46. $C_{17}H_{16}O_4NCl$. Calculated %: N 4.19; Cl 10.62.

III. N-(p-Tolyl)-6-methyllepidinium perchlorate. The product was prepared as (I) (Experiment 1); from 10 g of di-p-tolylamine there was obtained 3.5 g (17%), m. p. 150°. N-(p-Tolyl)-6-methyllepidinium perchlorate is reported for the first time.

Found %: N 4.15; Cl 10.33. Calculated %: N 4.03; Cl 10.20.

IV. N-(2',4'-Dimethylphenyl)-6,8-dimethyllepidinium perchlorate. This was synthesized like the preceding. From 10 g of 2,2',4,4'-tetramethyldiphenylamine and 1.3 g of paraformaldehyde there was obtained 3.25 g (19%) of the substance, m. p. 233°. The salt is reported for the first time.

Found %: N 3.48; Cl 9.60. $C_{20}H_{22}O_4NCl$. Calculated %: N 3.73; Cl 9.44.

SUMMARY

It has been established that diarylamines enter into co-condensation with formaldehyde and ketones, N-aryllepidinium salts being formed in 15-19% yield.

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* When methyl ethyl ketone was used in the reaction, addition of nitrobenzene did not increase the yield of the quaternary salt.
** Original Russian pagination. See C. B. Translation.

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ON REPLACEMENT OF HALOGEN IN AZO COMPOUNDS

VII. REPLACEMENT OF CHLORINE IN 2-HYDROXY-8'-CHLORO-(1,1')-AZONAPHTHALENE BY ARYLOXY GROUPS

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In a work by one of us and V. A. Savel'ev [1], the interaction of 2-hydroxy-8'-chloro-(1,1')-azonaphthalene (the azo dye from 1-amino-8-chloronaphthalene and 2-naphthol) and its cupric complex, with sodium methoxide was studied; in this case, it was shown that quantitative replacement of the chlorine atom by the methoxy group readily takes place in the presence of copper sulfate in the first case and without addition of the free copper salt in the second case. It was of interest to investigate the possibility of replacement of chlorine in this perichloro-o'-hydroxy azo dye by an aryloxy group. This was occasioned by the fact that in the Delfs patent [2], in which the possibility of replacement of chlorine in dyes of a similar type is mentioned, a solitary example is given, relating to the reaction with ethanol; interaction with phenols is not described. The possibility of replacement by aryloxy groups, of the halogen atom in o-halo-o'-hydroxy azo compounds, the mobility of halogen in which is comparable with that in perihalo-o'-hydroxy azo compounds, was shown earlier [3, 4].

In the present work, it has been established that the reaction does not take place when the original dye interacts with phenoxide in an aqueous medium in the presence of copper sulfate on heating for 10 hours at 105-110°, i.e., under conditions under which the analogous reaction with o-chloro-o'-hydroxy azo dyes goes without difficulty [3, 4]. The use of dioxane as solvent (and cupric acetate as the copper salt) made it possible to carry out the reaction within 4 hours at 100° with 84-86% yield. Dioxane proved to be a very convenient solvent, since the final products are easily isolated from it by diluting the reaction mass with water (or 10% sulfuric acid, which simultaneously breaks up the copper complex of the substituted dye).

Ar = C_6H_5, p-$CH_3C_6H_4$.
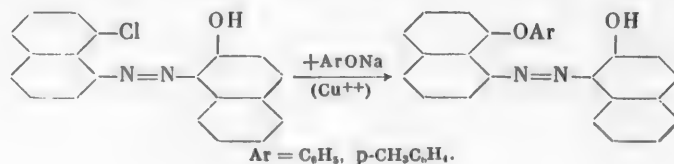
EXPERIMENTAL

2-Hydroxy-8'-chloro-(1,1')-azonaphthalene was prepared according to the cited work [1]; m. p. 161-162°.

Replacement of chlorine by aryloxy groups. Solutions of 1.66 g of the original dye in 70 ml of dioxane and 0.5 g of cupric acetate in 70 ml of dioxane were added to the sodium phenoxide or p-toloxide solution prepared by the reaction of 2.8 g of phenol or 3.3 g of p-cresol with 0.46 g of metallic sodium in 70 ml of dioxane at 100°, and the mixture was refluxed, with stirring, for 4 hours at 100°. The reaction mass was stirred for 30 minutes more with 200 ml of 10% sulfuric acid and left overnight, after which the precipitate formed was filtered out, treated with 100 ml of hot 1% sodium hydroxide solution in order to remove residual phenol, washed with warm water to remove the alkali, and dried at 70-80°. A test for chlorine was negative.

2-Hydroxy-8'-phenoxy-(1,1')-azonaphthalene was obtained in the quantity 1.65 g (84.6%). Recrystallization from dichloroethane gave purple plates with m. p. 225-226°. In the cold the dye was very soluble in benzene, toluene, dioxane, dichloroethane, and glacial acetic acid, moderately soluble in methanol and ethanol, slightly soluble in petroleum ether, and insoluble in water.

Found %: C 79.90; H 4.52; N 7.31. $C_{26}H_{18}O_2N_2$. Calculated %: C 79.98; H 4.64; N 7.17.

2-Hydroxy-8'-p-toloxy-(1,1')-azonaphthalene was obtained in the quantity 1.8 g (90%). Recrystallization from dichloroethane gave fine, bluish-violet needles with m. p. 193-194°. In the cold the dye was very soluble in benzene, toluene, chloroform, and dichloroethane, moderately soluble in carbon tetrachloride and glacial acetic acid, and slightly soluble in methanol, ethanol, and petroleum ether; on heating, it was very soluble in carbon tetrachloride and glacial acetic acid, moderately soluble in methanol and ethanol, slightly soluble in petroleum ether, and insoluble in water.

Found %: C 80.39; H 5.13; N 7.14. $C_{27}H_{20}O_2N_2$. Calculated %: C 80.18; H 4.98; N 6.92.

SUMMARY

In the reaction of 2-hydroxy-8'-chloro-(1,1')-azonaphthalene with sodium phenoxide or p-toloxide in dioxane in the presence of a copper salt the chlorine atom was replaced by a phenoxy or p-toloxy group. It was found that, in contrast to the case of analogous dyes with a chlorine atom in the ortho-position relative to the azo group, the stated reaction does not occur in the case of a perichloro-substituted azo dye in an aqueous-alkaline medium under mild conditions (heating without pressure).

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INVESTIGATIONS IN THE FIELD OF ORGANIC SCINTILLATORS

## IV. SYNTHESIS OF PARA-SUBSTITUTED 2,5-DIPHENYL-1,3,4-OXADIAZOLES

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For the purpose of systematic study of the relation between scintillation properties and structure in a series of oxadiazole derivatives, we synthesized the following series of derivatives, previously unknown in the literature, of 2,5-diphenyl-1,3,4-oxadiazole with various functional substituents located in the para-position of one of the benzene rings:

where $R = NO_2, NH_2, NHCOCH_3, OH, OCH_3, OCOCH_3, Cl, Br, I$.
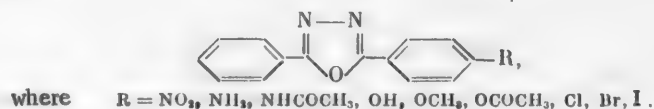
These compounds were usually synthesized according to Scheme (1), which is general for many substances of similar type [1].

$$(1)$$
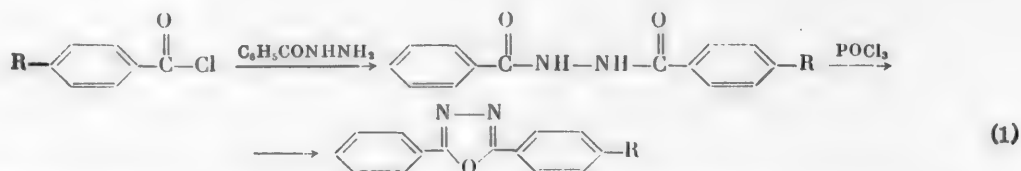
However, the given reaction is unsuitable for oxadiazole derivatives whose functional groups (e.g., amino or hydroxyl) are themselves capable of interacting with the reagents used here. In these cases, therefore, we employed Scheme (2), which had never before been used for the preparation of such compounds.

$$(2)$$
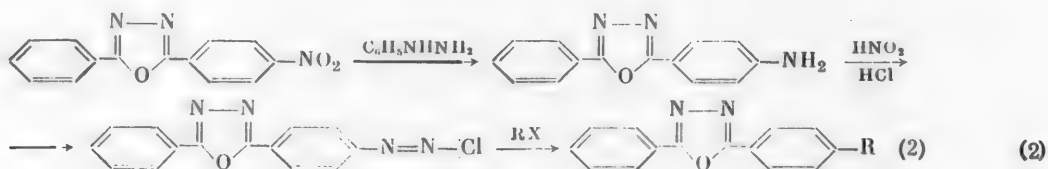
In Scheme (2) the stage of reduction of the nitro group to an amino group and the subsequent replacement of the latter by other functional substituents are of interest.

As we established earlier, the oxadiazole ring is sensitive to the action of aqueous solutions of mineral acids and alkalis, especially at elevated temperatures, which leads to decomposition of the heterocyclic ring first to the corresponding hydrazide and then to hydrazine and aromatic acids. In connection with this, we were

unable to prepare 2-phenyl-5-(4-aminophenyl)-1,3,4-oxadiazole in satisfactory yield by reduction of the corresponding nitro derivative of oxadiazole with reducing agents acting in acid or alkaline media. Good results were obtained only when phenylhydrazine was used as a reducing agent.

In the course of the present investigation it was found that the amino group located in the para-position of 2,5-diphenyl-1,3,4-oxadiazole readily enters into reactions characteristic of the primary aromatic amino group; this made it possible to prepare a number of new derivatives of 1,3,4-oxadiazole, which were very important for scintillation purposes; their countersynthesis according to Scheme (1) fully confirmed their chemical structure.

In the synthesis of some of the above-mentioned oxadiazoles the intermediate products from which they were obtained also proved to be unreported.

EXPERIMENTAL

Synthesis of 2-phenyl-5-(4-aminophenyl)-1,3,4-oxadiazole. a) 1-Benzoyl-2-(4-nitrobenzoyl)hydrazine. To 278 g of 4-nitrobenzoyl chloride, dissolved in 1 liter of dry pyridine, was added 204 g of benzohydrazide [2] in such a way that the reaction was not very vigorous. The reaction mass was then heated to boiling and boiled for 30 minutes, after which the resulting solution was filtered while hot in order to remove a small amount of an insoluble precipitate consisting of nearly pure 1,2-di-(4-nitrobenzoyl)hydrazine, and the filtrate was poured into a large amount of cold water. The precipitated crystalline product was filtered out, thoroughly washed with water, and dried. Yield 200 g (46.9%) after recrystallization from 1 liter of glacial acetic acid; m. p. 228-230° (according to the cited work [3], 236°).

b) 2-Phenyl-5-(4-nitrophenyl)-1,3,4-oxadiazole. A mixture of 150 g of 1-benzoyl-2-(4-nitrobenzoyl)-hydrazine and 450 ml of POCl$_3$ was boiled in an air bath for 10 hours. Then the reaction mass was cautiously poured into 6 kg of ice. The resulting oxadiazole was filtered, washed on the filter with water, and dried. Yield, quantitative; m. p. 201-203°. After recrystallization from glacial acetic acid, m. p. 207-209° (according to the cited work [3], 209°).

c) 2-Phenyl-5-(4-aminophenyl)-1,3,4-oxadiazole. A mixture of 20.7 g of 2-phenyl-5-(4-nitrophenyl)-1,3,4-oxadiazole and 67.5 ml of freshly distilled phenylhydrazine was cautiously heated in an air bath. The solid matter gradually dissolved, the solution becoming dark-red. When the temperature of the reaction mass reached 110-115°, the reaction began to proceed vigorously with intense development of heat and copious evolution of nitrogen. To avoid ejection of the reaction mass, it was advisable not to heat the latter above the stated temperature. The reduction was finished within 75-90 minutes, as could be deduced from the cessation of nitrogen evolution. The reaction product was then poured into 150 ml of benzene; a crystalline precipitate immediately formed, which was filtered, washed on the filter with benzene, and dried. Yield 15.5 g (84.2%); m. p. 186-187°. After several recrystallizations from ethanol and toluene, m. p. 191.5-192°. A light-yellow, crystalline product, very soluble in glacial acetic, sulfuric, and hydrochloric acids, moderately soluble in ethanol, toluene, and benzene, nearly insoluble in petroleum ether and water. With mineral acids it gave salts.

Found %: N 17.77. C$_{14}$H$_{11}$ON$_3$. Calculated %: N 17.65.

Synthesis of 2-phenyl-5-(4-acetamidophenyl)-1,3,4-oxadiazole. A 2.4 g quantity of 2-phenyl-5-(4-aminophenyl)-1,3,4-oxadiazole was dissolved in 10 ml of benzene and 1.1 ml of acetic anhydride added dropwise with stirring. The resulting mixture was then boiled for 20 minutes, and the precipitate which formed after cooling was filtered out and dried. Yield 2.5 g (88.6%); m. p. 273-274°. After several recrystallizations from pyridine and glacial acetic acid, m. p. 278°. A colorless, crystalline substance, very soluble in pyridine, glacial acetic acid, and nitrobenzene and slightly soluble in toluene and ethanol.

Found %: N 15.11. C$_{16}$H$_{13}$O$_2$N$_3$. Calculated %: N 15.05.

Synthesis of 2-phenyl-5-(4-hydroxyphenyl)-1,3,4-oxadiazole. A 4.7 g quantity of 2-phenyl-5-(4-amino-phenyl)-1,3,4-oxadiazole was dissolved in 80 ml of 2% hydrochloric acid, cooled to 0°, and diazotized with a solution of 1.5 g of sodium nitrite in 15 ml of water. After all the sodium nitrite was added, the resulting mixture was stirred for 10-15 minutes with cooling (if a small amount of solid matter was present, it was advisable to filter the solution) and then slowly heated to 80-90°. The crystalline precipitate formed was filtered out, washed

on the filter with water and dried. Yield 1.7 g (36%); m. p. 250-251°. After recrystallization from alcohol and nitrobenzene, m. p. 254.5-255°. A colorless, crystalline substance, slightly soluble in benzene, toluene, and ethanol, moderately soluble in nitrobenzene and glacial acetic acid, and very soluble in alkalis.

Found %: N 11.68. $C_{14}H_{10}O_2N_2$. Calculated %: N 11.76.

Synthesis of 2-phenyl-5-(4-methoxyphenyl)-1,3,4-oxadiazole. A. Synthesis according to Scheme (1). a) 1-Benzoyl-2-(4-methoxybenzoyl)hydrazine. Seventy-five ml of benzoyl chloride was dissolved in 300 ml of pyridine, and 105 g of 4-methoxybenzoylhydrazine [4] was added to the solution obtained. The resulting mixture was then boiled for 20 minutes and poured into water. Yield 165 g (96.5%); m. p. 183°. After several recrystallizations from ethanol, m. p. 186-187°.

Found %: N 10.37. $C_{15}H_{14}O_3N_2$. Calculated %: N 10.37.

b) 2-Phenyl-5-(4-methoxyphenyl)-1,3,4-oxadiazole. A mixture of 93 g of 1-benzoyl-2-(4-methoxy-benzoyl)hydrazine and 280 ml of $POCl_3$ was boiled for 12 hours, the bulk of the phosphorus oxychloride was then distilled off, and the residue was poured into cold water. The crystalline product formed was recrystallized from ethanol. Yield 56 g (64.5%); m. p. 141°. After several recrystallizations from ethanol and toluene, m. p. 146°.

Found %: N 11.16. $C_{15}H_{12}O_2N_2$. Calculated %: N 11.11.

B. Synthesis according to Scheme (2). A 0.24 g quantity of 2-phenyl-5-(4-hydroxyphenyl)-1,3,4-oxadiazole was dissolved in 0.9 ml of 5% alkali, and 0.1 ml of dimethyl sulfate was added to the solution obtained. After brief heating a crystalline precipitate formed, which was filtered out and dried. Yield 0.2 g (79.5%); m. p. 155-157°. After recrystallization from alcohol, m. p. 146-146.5°. A colorless, crystalline substance, very soluble in organic solvents.

Synthesis of 2-phenyl-5-(4-acetoxyphenyl)-1,3,4-oxadiazole. A 0.7 g quantity of 2-phenyl-5-(4-hydroxy-phenyl)-1,3,4-oxadiazole was dissolved in 10 ml of pyridine and 0.9 ml of acetyl chloride gradually added to the resulting solution. After the reaction mixture had stood for a day at room temperature, water was added. The crystalline precipitate formed was filtered out and dried. Yield 0.4 g (48.6%); m. p. 149°. After recrys-tallization from toluene, m. p. 149°. A colorless, crystalline substance, moderately soluble in organic solvents.

Found %: N 8.71. $C_{16}H_{12}O_3N_2$. Calculated %: N 8.67.

Synthesis of 2-phenyl-5-(4-chlorophenyl)-1,3,4-oxadiazole. Synthesis according to Scheme (1). 22 g of 1-benzoyl-2-(4-chlorobenzoyl)hydrazine [5] and 280 ml of $POCl_3$ were boiled for 90 minutes, after which the bulk of the $POCl_3$ was distilled off and the residue poured into 200 ml of water. The crystalline reaction product was filtered out and dried. Yield 19.5 g (94.8%); m. p. 147-148°. After several recrystallizations from ethanol and toluene, m. p. 162°.

Found %: N 10.99. $C_{14}H_9ON_2Cl$. Calculated %: N 10.92.

Synthesis according to Scheme (2). A 4.7 g quantity of 2-phenyl-5-(4-aminophenyl)-1,3,4-oxadiazole was mixed with 80 ml of concentrated hydrochloric acid. The resulting mixture was cooled to 0° and diazotized with a solution of 1.5 g of sodium nitrite in 15 ml of water. The diazonium salt solution formed was slowly added to a mixture composed of 20 ml of concentrated hydrochloric acid, cuprous chloride, and copper powder; the resulting mixture was then gradually heated until all the nitrogen was evolved, after which the precipitated reaction product was filtered out and dried. Yield 4.5 g (88.5%), m. p. 153°. After several recrystallizations from ethanol and toluene, m. p. 162-163°. A mixture test of this sample with the product obtained according to Scheme (1) gave no melting point depression. A colorless, crystalline product, very soluble in all organic solvents and insoluble in water.

Synthesis of 2-phenyl-5-(4-bromophenyl)-1,3,4-oxadiazole. A. Synthesis according to Scheme (1). a) 1-Benzoyl-2-(4-bromobenzoyl)hydrazine. To a solution of 55 g of 4-bromobenzoyl chloride in 200 ml of pyridine was added 34 g of benzohydrazide [2], after which the mixture obtained was boiled for 20 minutes and poured into 0.5 liter of cold water. The colorless product which precipitated was filtered out and dried. After recrystallization from ethanol, yield 48.5 g (60.0%); m. p. 210°. After several recrystallizations from ethanol, m. p. 216°.

Found %: N 8.88. $C_{14}H_{11}O_2N_2Br$. Calculated %: N 8.77.

b) 2-Phenyl-5-(4-bromophenyl)-1,3,4-oxadiazole. 18 g of 1-benzoyl-2-(4-bromobenzoyl)hydrazine was boiled with 50 ml of $POCl_3$ for 1 hour; 25 ml of $POCl_3$ was then distilled off and the residue poured into cold water. A colorless, crystalline precipitate formed, which was filtered out and dried. Yield, quantitative; m. p. 164°. After recrystallization from toluene and chromatographic purification with aluminum oxide, m. p. 167°.

Found %: N 9.52. $C_{14}H_9ON_2Br$. Calculated %: N 9.30.

B. Synthesis according to Scheme (2). A solution of 1.2 g of 2-phenyl-5-(4-aminophenyl)-1,3,4-oxadiazole in 40 ml of concentrated hydrobromic acid was diazotized by a solution of 0.4 g of sodium nitrite in 4 ml of water. The resulting diazonium salt solution was poured into hydrobromic acid containing a small amount of copper powder. After initial heating of the reaction mass there was obtained about 1 g (65.5%) of the oxadiazole, which, according to its properties, was identical with the 2-phenyl-5-(4-bromophenyl)-1,3,4-oxadiazole prepared according to Scheme (1). A colorless, crystalline product, moderately soluble in organic solvents and insoluble in water.

Synthesis of 2-phenyl-5-(4-iodophenyl)-1,3,4-oxadiazole. A 4.8 g quantity of 2-phenyl-5-(4-amino-phenyl)-1,3,4-oxadiazole was suspended in 80 ml of concentrated hydrochloric acid, cooled to 0°, and diazotized with a solution of 1.3 g of sodium nitrite in 16 ml of water. The resulting diazonium salt solution was slowly poured into a previously prepared solution consisting of 6.8 g of KI, 2.6 g of iodine, and 12 ml of water. Then the mixture obtained was slowly heated until nitrogen evolution ceased completely, the excess iodine was bound by means of bisulfite solution, and the precipitated product was filtered out and dried. After three recrystallizations from aqueous pyridine (1:2), using charcoal, the yield was 1.5 g (21.3%); m. p. 158-158.5°. A colorless, crystalline substance, very soluble in pyridine and dioxane, moderately soluble in ethanol, benzene, and acetic acid, and insoluble in water.

Found %: N 8.42. $C_{14}H_9ON_2I$. Calculated %: N 8.05.

SUMMARY

1. A new method of synthesis of functional derivatives of oxadiazole has been developed.

2. Nine new p-substituted 2,5-diphenyl-1,3,4-oxadiazoles have been synthesized and their properties studied.

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TRANSFORMATIONS IN THE SERIES OF DIAZOAMINO COMPOUNDS

## II. THERMAL DECOMPOSITION OF SUBSTITUTED 1,3-ANTHRAQUINONYLPHENYLTRIAZENES

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Using the thermal decomposition of diazoaminobenzene-4,4'-dicarboxylic acid as an example, it was shown by A. I. Kizber [1] that diarylamines can be obtained from diazoamino compounds. Later Kizber and the author [2] found that in organic media, at 270-290°, the dipotassium salt of diazoaminobenzene-4,4'-dicarboxylic acid (I) gives diphenylamine-4,4'-dicarboxylic acid in 60-65% yield. Under the same conditions, the potassium salts of 4'-chloro- (II) and 4'-methyldiazoaminobenzene-4-carboxylic (III) acids give the 4'-chloro- and 4'-methyl-diphenylamine-4-carboxylic acids [2].

Primary aromatic amines (up to 30%) were also isolated from the transformation products of the indicated triazenes. The decomposition of (I) gave p-aminobenzoic acid, while the decomposition of the unsymmetrical diazoamino compounds (II and III) revealed that two primary amines were formed: p-aminobenzoic acid and respectively p-chloroaniline and p-toluidine. To explain this fact, it is necessary to assume that unsymmetrical diazoamino compounds show a dual reactivity when subjected to thermal decomposition, corresponding to the two forms: $RNHN=NR_1$ (A) and $RN=NNHR_1$ (B).

It is known that the hydrolytic cleavage of unsymmetrical 1,3-triazenes yields products corresponding to the two types of structures possible for triazenes. As a rule, a decision as to the quantitative proportions of the two forms of the starting triazene (A and B) is based on quantitatively determining the amounts of the two primary amines in the products of the acid cleavage of the diazoamino compound (Scheme 1).
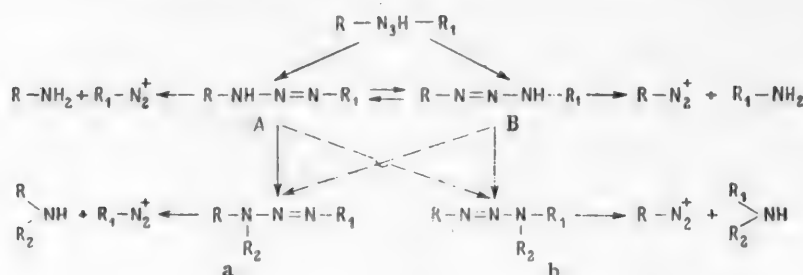

Using a similar method, it was shown by I. S. Ioffe and A. P. Ershov [3] that the ratio of the tautomeric forms of aromatic triazenes is determined by the character of the substituents and their location in the benzene ring.

A second method of establishing the structure of diazoamino compounds is to fix the tautomeric forms by replacing the hydrogen of the imino group by an acid or some other radical, followed by hydrolytic cleavage [4, 5]. Here unsymmetrical triazenes give two series of transformation products. However, it must be kept in mind that in most cases the data pertaining to the ratios of two tautomeric forms relate to the equilibrium (or

close to it) state of these forms in solution. In addition, in the second case, it is quite possible for the reaction center to transfer when the hydrogen is replaced by some radical. In such case, it is possible for triazene (a) to also arise from form (B), and for triazene (b) to arise from form (A) (Scheme 1). Since the formation rate of triazene (a) from different forms can differ, the ratio of the two amines, $RNHR_2$ and R_1NHR_2, will differ from the ratio of the two tautomers, (A) and (B).

In contrast to hydrolytic cleavage, the thermal decomposition of the potassium salts of diazoamino compounds (I - III) goes in the solid phase at a rapid rate (almost instantaneously). This makes it impossible for tautomeric equilibrium of the two forms (A) and (B) to become established. The possibility of transfer of the reaction center is also absent here, since the thermal decomposition of triazenes bears a homolytic character. Under these conditions, it is possible for amine RNH_2 to be formed only from structure (A), and amine R_1NH_2 to be formed only from structure (B) (Scheme 2).

$$R-N_3H-R_1$$
$$R-NH-N=N-R_1 \qquad R-N=N-NH-R_1$$
$$(A) \qquad (B)$$
$$R-NH_2 \ + \ R-NH-R_1 \ + \ R_1-NH_2$$
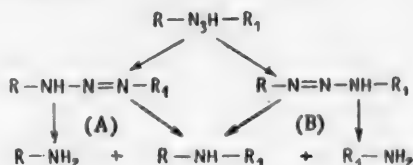
Consequently, the fact that two primary amines are formed in the thermal decomposition of unsymmetrical triazenes indicates the dual reactivity shown by the latter under conditions excluding tautomerism. It is entirely probable that the crystal of an unsymmetrical triazene is built from different molecules, the structures of which correspond to the two possible structures (A) and (B). Special physicochemical studies are needed to verify such a postulation. In any case, the formation of primary amines of different structure in the thermal decomposition of diazoamino compounds makes it possible to arrive at some conclusions regarding the influence of substituents and of steric factors on the stabilization of individual structures.

It seemed of interest to follow similar transformations of aromatic diazoamino compounds containing the anthraquinone radical: for example, 1-(1'-anthraquinonyl)- and 1-(2'-anthraquinonyl)-3-phenyltriazenes, to substituted 1- and 2-phenylaminoanthraquinones. For this purpose, we prepared 1-(1'-anthraquinonyl)-3-p-carboxyphenyl- (IV), 1-(1'-anthraquinonyl)-3-p-tolyl- (V), 1-(2'-anthraquinonyl)-3-p-carboxyphenyl- (VI) and 1-(2'-anthraquinonyl)-3-p-tolyltriazene (VII). Since it is possible for an intramolecular hydrogen bond to be formed in 1,3-anthraquinonylphenyltriazenes, it could be expected that (IV) and (V) will react in the tautomeric form (C).

(C)
(IV) R = COOH

(D)
(V) R = CH₃

(E)
(VI) R = COOH

(F)
(VII) R = CH₃
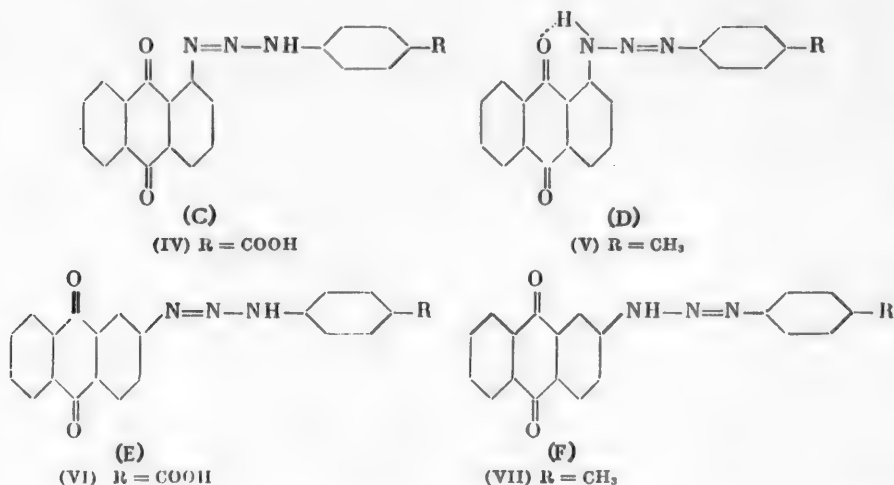
Diazoamino compounds (IV) and (VI), as the potassium salts, were added rapidly to anthracene, or to dibutyl phthalate, heated at 275-290°, and the mixture stirred for several minutes. After cooling, the reaction products were separated either by fractional solution, crystallization, or chromatographing on Al_2O_3.

Thermal decomposition of the potassium salts of (IV) (in anthracene) and (VI) (in dibutyl phthalate) gave in 52-45% yield, respectively the 1- and 2-p-carboxyphenylaminoanthraquinones (VIII and X). In addition, 1-aminoanthraquinone (in up to 33% yield) and p-aminobenzoic acid were isolated in the decomposition of (IV), while 2-aminoanthraquinone and p-aminobenzoic acid were isolated in the decomposition of (VI).

Replacing the carboxyl group by the methyl radical (V and VII) causes a substantial reduction in the yield of the substituted phenylaminoanthraquinone; at the same time, the amount of the aminoanthraquinone increases. Thus, 1-p-tolylaminoanthraquinone (IX) (21%) and 1-aminoanthraquinone (51%) were obtained from the decomposition of (V) in dibutyl phthalate.

The decomposition of (VII) in anthracene gave a 5% yield of 2-p-tolylaminoanthraquinone (XI). The same reaction also led to the isolation of 2-aminoanthraquinone (about 52% yield). On the basis of the data obtained for the thermal decomposition of (IV) - (VII) it becomes possible to arrive at a conclusion as to the structure of the 1-(1'-anthraquinonyl)- and 1-(2'-anthraquinonyl)-3-phenyltriazenes. According to the synthesis, the structure of the 3-p-carboxyphenyl- and 3-p-tolyl-1-(1'-anthraquinonyl)-triazenes should correspond to structure (C). In such case the primary amine found in the decomposition products should belong to the benzene series, and specifically, should be p-aminobenzoic acid (from IV) and p-toluidine (from V). Neither of these

(VIII) R = COOH; (IX) R = CH₃; (X) R = COOH; (XI) R = CH₃.
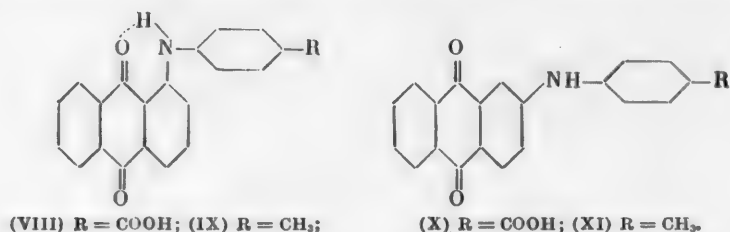
compounds could be isolated when (IV) and (V) were subjected to decomposition; in both cases only 1-aminoanthraquinone was isolated. The formation of the latter is possible from structure (D), stabilized by intramolecular hydrogen bonding.

The presence of hydrogen bonding in 1-N-substituted (amino, alkylamino and arylamino) anthraquinones was shown recently by physicochemical methods [6].

The formation of two primary amines, corresponding to the two structures (E and F) possible for triazenes, could be expected in the case of the 1-(2'-anthraquinonyl)-3-phenyltriazenes. Actually, besides 2-amino-anthraquinone, we isolated p-aminobenzoic acid from the decomposition products of (VI). The formation of 2-aminoanthraquinone is possible from structure (F), while p-aminobenzoic acid should be obtained from structure (E). The decomposition of (VII) led to the isolation of only one primary amine, namely 2-aminoanthraquinone, corresponding to the isomeric form (F); p-toluidine was not found in the decomposition products. Stabilization of structure (F) is probably due to the electronegative nature of the anthraquinone ring.

The isolated amines of the anthraquinone series were identified by comparing them with the starting aminoanthraquinones, taken to prepare (IV - VII). 4-Aminobenzoic acid was converted to 4-chlorobenzoic acid, and identified by mixed melting point with the authentic compound.

The structure of the substituted phenylaminoanthraquinones was shown by counter synthesis. To synthesize (VIII), obtained from (IV), we took 1-chloroanthraquinone and p-aminobenzoic acid as the starting materials. We were unable to obtain 2-p-carboxyphenylaminoanthraquinone from 2-aminoanthraquinone and methyl p-bromobenzoate in boiling nitrobenzene. Heating 2-chloroanthraquinone with methyl p-aminobenzoate at 240 to 250° also failed to give the desired result.

Decarboxylation of (X) gave 2-phenylaminoanthraquinone, identical with the substance obtained from 2-chloroanthraquinone and aniline.

To synthesize (IX), we reacted 1-chloroanthraquinone with p-toluidine in butanol under conditions close to those described in the patent [7]. To synthesize (XI) from 2-chloroanthraquinone and p-toluidine requires more drastic conditions (absence of solvent, temperature above 200°).

Preparation of Starting Triazenes

1-(1'-Anthraquinonyl)-3-p-carboxyphenyltriazene (IV). A water solution (about 2 liters) of 1-anthra-quinonediazonium sulfate (obtained by the diazotization of 10 g of 1-aminoanthraquinone in concentrated H_2SO_4 with dry $NaNO_2$ [8]) was added to a solution of 6.2 g of p-aminobenzoic acid, 1.85 g of sodium hydroxide and 15.5 g of CH_3COONa in 100 ml of water at room temperature, after which the mixture was stirred for 2 hours, filtered, and the product washed with water, alcohol, and boiling ethyl acetate. Yield 12.1 g (72%). Orange needles (from ethyl acetate). M. p. 209-210° (with decomp.).

Found %: N 11.54, 10.95. $C_{21}H_{13}O_4N_3$. Calculated %: N 11.32.

1-(1'-Anthraquinonyl)-3-p-tolyltriazene (V). A suspension of 1-anthraquinonediazonium sulfate (0.045 g-mole) in 150 ml of water was added to a solution of 5 g of p-toluidine and 15.5 g of CH_3COONa in 75 ml of methanol at room temperature, and the mixture stirred for 1 hour. Then the product was filtered, followed by washing with water, alcohol, and hot ethyl acetate. Yield 11.5 g (75%). Red needles (from ethyl acetate). M. p. 210-211° (with decomp.).

Found %: N 12.13, 12.06. $C_{21}H_{15}O_2N_3$. Calculated %: N 12.31.

1-(2'-Anthraquinonyl)-3-p-carboxyphenyltriazene (VI). Obtained in the same manner as (IV) from 2-anthraquinonediazonium sulfate [9] and p-aminobenzoic acid. Yellow needles (from ethyl acetate). M. p. 220-221° (with decomp.).

Found %: N 10.90, 10.74. $C_{21}H_{13}O_4N_3$. Calculated %: N 11.32.

1-(2'-Anthraquinonyl)-3-p-tolyltriazene (VII). Obtained in the same manner as (V). Yield 74%. Orange crystals (from ethyl acetate). M. p. 215-216° (with decomp.).

Found %: N 12.21, 12.18. $C_{21}H_{15}O_2N_3$. Calculated %: N 12.31.

The potassium salts of (IV) and (VI) were obtained by neutralizing the respective acids with the calculated amount of potassium hydroxide solution, followed by evaporation in vacuo, and drying over P_2O_3.

Decomposition of the potassium salts of 1-(1'-anthraquinonyl)-3-p-carboxyphenyltriazene (IV) and 1-(2'-anthraquinonyl)-3-p-carboxyphenyltriazene (VI).

1. The dry potassium salt (5.5 g) of (IV) was added rapidly to 30 g of anthracene at 280°, and the mixture stirred for 3-4 minutes. The mass was cooled, ground, and extracted with chlorobenzene. The red-brown insoluble portion (3.75 g) was recrystallized from a large volume of water. The obtained crystals (dark red needles) were filtered, and after acidification with dilute HCl we obtained 1-p-carboxyphenylaminoanthraquinone. M. p. 292-294°. Yield 2.4 g (52%). Red needles; m. p. 299-300° (from glacial acetic acid).

Found %: N 4.49, 4.51. $C_{21}H_{13}O_4N$. Calculated %: N 4.08.

The mixed melting point of the above with the substance (m. p. 301-302°), synthesized from 1-chloroanthraquinone and p-aminobenzoic acid, was 299-301°. From the chlorobenzene extract, by fractional crystallization and chromatographing on Al_2O_3, we isolated 1 g of substance with m. p. 248-250°. Red needles; m. p. 252-253° (from chlorobenzene). The mixed melting point with 1-aminoanthraquinone was not depressed.

2. The dry potassium salt (11 g) of (VI) was added rapidly to 55 g of dibutyl phthalate at 270°, the temperature of the mixture raised to 285-290°, and the mixture stirred for another 12-15 minutes. After cooling to 80°, the mass was diluted with benzene (100 ml), and the obtained precipitate was filtered and then washed with benzene until the filtrate was colorless. Extraction with 10% aqueous alcohol and acidification with dilute HCl gave 4.2 g of (X) with m. p. 318-320°. Red needles; m. p. 323-325° (from a mixture of glacial CH_3COOH and ethyl acetate).

Found %: N 3.84, 3.89. $C_{21}H_{13}O_4N$. Calculated %: N 4.08.

Decarboxylation of (X) (heating with Cu + CuO in vacuo) gave a substance with m. p. 237-239°, in its properties corresponding to 2-anilinoanthraquinone.

Found %: N 4.99, 5.01. $C_{20}H_{13}O_2N$. Calculated %: N 4.68.

The melting point was not depressed when this substance was mixed with authentic 2-anilinoanthraquinone.

The hydrochloric acid filtrate [after the removal of (X)] was diazotized with $NaNO_2$, followed by decomposition of the obtained diazonium salt in the presence of Cu_2Cl_2, to give a colorless substance with m. p. 239 to 240°, which failed to depress the melting point when mixed with authentic p-chlorobenzoic acid (the melting point of the mixture was 239.5-240.5°). The benzene wash liquor was added to the main filtrate, the benzene was distilled off, and then the dibutyl phthalate (in vacuo), after which the residue was recrystallized from chlorobenzene, and then sublimed. Orange needles. M. p. 301-302°. The mixed melting point with the 2-aminoanthraquinone (m. p. 302-304°), taken to prepare triazene (VI), was 301-303°.

Decomposition of 1-(1'-anthraquinonyl)-3-p-tolyltriazene (V). Ten grams of (V) was added to 50 ml of heated dibutyl phthalate, the temperature of the mass raised to 285-290° (copious evolution of gases observed), and the mixture stirred for 5 minutes at this temperature. Then the dibutyl phthalate was removed by vacuum-distillation (176-178° at 4 mm). The residue was dissolved in chlorobenzene and the solution chromatographed on Al_2O_3. We obtained 1.9 g of 1-p-tolylaminoanthraquinone; m. p. 152-154°. Ruby red needles (from butanol). M. p. 159-160°.

Found %: C 80.63; H 4.90; N 4.12. $C_{21}H_{15}O_2N$. Calculated %: C 80.51; H 4.79; N 4.47.

The mixed melting point of this compound with the substance (m. p. 158-159°), obtained from 1-chloro-anthraquinone and p-toluidine, was 158.5-159.5°. In addition, we isolated 4 g of 1-aminoanthraquinone with m. p. 246-248°.

Decomposition of 1-(2'-anthraquinonyl)-3-p-tolyltriazene (VII). A mixture of 10 g of (VII) and 35 g of anthracene was heated to 210-215°, the mass permitted to melt, and then the temperature was raised with stirring to 275°, where it was kept for 5 minutes. Fractional crystallization and chromatographing on Al_2O_3 gave 3.4 g (52%) of 2-aminoanthraquinone with m. p. 301-303° and 0.45 g (5%) of 2-p-tolylaminoanthraquinone; m. p. 232-234°. Red crystals (from butanol). M. p. 235-236°.

Found %: N 4.37, 4.39. $C_{21}H_{15}O_2N$. Calculated %: N 4.47.

When mixed with the 2-p-tolylaminoanthraquinone, obtained by counter synthesis, the melting point was 235-236°.

1-p-Carboxyphenylaminoanthraquinone. A mixture of 1-chloroanthraquinone (0.03 g-mole), p-amino-benzoic acid (0.075 g-mole), sodium acetate (0.045 g-mole), copper acetate (0.3 g) and 45 ml of cyclo-hexanol was stirred at 160-162° for 8-10 hours, cooled to 120°, and diluted with an equal amount of butyl alcohol. The crystalline mass was pressed on the filter, washed with butyl alcohol, and recrystallized from a large volume of water with the addition of sodium carbonate. The sodium salt of 1-p-carboxyphenyl-1-amino-anthraquinone (spindle-shaped red crystals) deposited from the filtrate. Acidification with HCl gave the free 1-phenylaminoanthraquinone-4'-carboxylic acid. M. p. 296-298°. Yield 3.2 g (31%). Red needles (from a mixture of chlorobenzene and CH_3COOH). M. p. 301-302°.

2-Anilinoanthraquinone. A mixture of 2-chloroanthraquinone (0.03 g-mole), aniline (0.42 g-mole), anhydrous sodium acetate (0.045 g-mole) and cuprous chloride (0.003 g-mole) was heated in a sealed tube for 4 hours at 250-260° (bath temperature). The mass after cooling was treated with dilute HCl (10%), filtered, and washed with water. The substance was purified by chromatographing on Al_2O_3 in chlorobenzene. Golden-orange plates. M. p. 238-239° (234-236° [10]; 238-239° [11]). Yield 4.9 g (53%).

1-p-Tolylaminoanthraquinone. A mixture of 1-chloroanthraquinone (0.04 g-mole), p-toluidine (0.08 g-mole), anhydrous potassium acetate (0.08 g-mole), copper acetate (0.2 g) and butyl alcohol (50 ml) was refluxed for 6 hours. After cooling, the crystalline mass was pressed on the filter, and then washed with methanol and water. The substance was purified by chromatographing on Al_2O_3 (in chlorobenzene) and recrystallization from butanol. Ruby red needles. M. p. 158-159°. Yield 3.8 g (30%).

2-p-Tolylaminoanthraquinone was obtained in the same manner as 2-anilinoanthraquinone by heating 2-chloroanthraquinone (7.5 g), p-toluidine (37.5 g), anhydrous potassium acetate (3.8 g) and Cu_2Br_2 (0.5 g) in a sealed tube. Yield 3.35 g (33.5%). M. p. 236-237° (234-235° [10]).

SUMMARY

1. It was shown that the thermal decomposition at 270-290°, in organic media, of the potassium salts of 1-(1'-anthraquinonyl)- and 1-(2'-anthraquinonyl)-3-p-carboxyphenyltriazenes gives in 45-52% yield the 1- and 2-p-carboxyphenylaminoanthraquinones. Under the same conditions, the potassium salts of 1-(1'-anthraquinonyl)- and 1-(2'-anthraquinonyl)-3-p-tolyltriazenes gave the 1- and 2-p-tolylaminoanthraquinones (5-20% yield). In addition to arylaminoanthraquinones, the decomposition of the indicated triazenes yields the primary aromatic amines: 1- and 2-aminoanthraquinones and p-aminobenzoic acid.

2. When subjected to thermal decomposition, 1-(1'-anthraquinonyl)-3-p-carboxyphenyltriazene, 1-(1'-anthraquinonyl)-3-p-tolyltriazene and 1-(2'-anthraquinonyl)-3-p-tolyltriazene react in the same isomeric form with involvement of the hydrogen atom attached to the nitrogen linked directly with the anthraquinone ring, which fully explains the formation of one primary amine (1- or 2-aminoanthraquinone). The decomposition of 1-(2'-anthraquinonyl)-3-p-carboxyphenyltriazene gave two primary amines, namely 2-aminoanthraquinone and p-aminobenzoic acid, corresponding to the two possible structures of the triazene.

3. The theory was expressed that for 1-(1'-anthraquinonyl)-3-phenyltriazenes a stabilization of the structure in which the hydrogen atom is attached to the nitrogen linked to the anthraquinone ring occurs as the result of the formation of an intramolecular hydrogen bond with the carbonyl of the anthraquinone. Stabilization of the corresponding form for the case of 1-(2'-anthraquinonyl)-3-p-tolyltriazene is probably due to the electronegative nature of the anthraquinone ring.

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CYANINE DYES

## XIII. MONOMETHINEQUINOTHIACYANINES OF UNSYMMETRIC STRUCTURE

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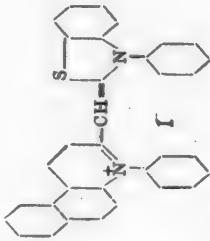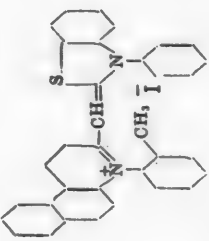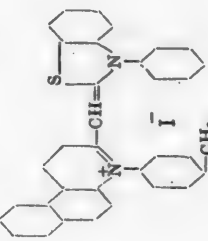
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Spectroscopic studies of cyanine dyes [1-3] have established that the intensity of absorption for the monomethinecyanines is approximately half of that shown by the corresponding carbocyanines. In addition, for the cyanines, as a rule, the absorption maximum with respect to the sensitizing maximum is shifted toward shorter wavelengths in the spectrum by approximately 25-30 mμ [4]. The monomethinecyanines described in the literature have alkyl radicals on the nitrogen hetero atom.

It seemed of interest to study the synthesis of monomethinecyanines of unsymmetric structure with aromatic and alkyl radicals substituted in the hetero portions of the molecules, and also the synthesis of dyes having only aromatic radicals. Such compounds are absent in [5]. Several references [6-8] exist in the literature regarding monomethinecyanines. The cyanines synthesized by us were obtained by reacting the quaternary salts of heterocyclic bases with thiazoloneimines and mercapto derivatives, or with quinolones, at the moment of their formation. In the first case, the fusion of the mixture of imine and quaternary salt was done in vacuo [9].
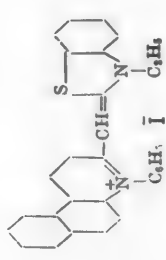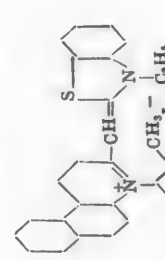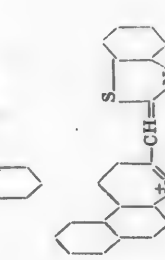
We also obtained a number of monomethinecyanines in which the methine linkage was found in the 2,2 and 2,4 positions. The reactions were run as depicted by the schemes [10]:

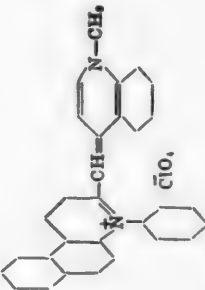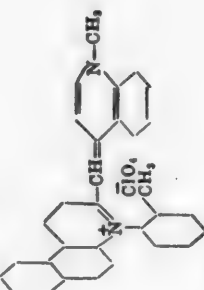where $Ar = C_6H_5, C_{10}H_7$; $R = CH_3, C_2H_5$; $X = I, ClO_4$.
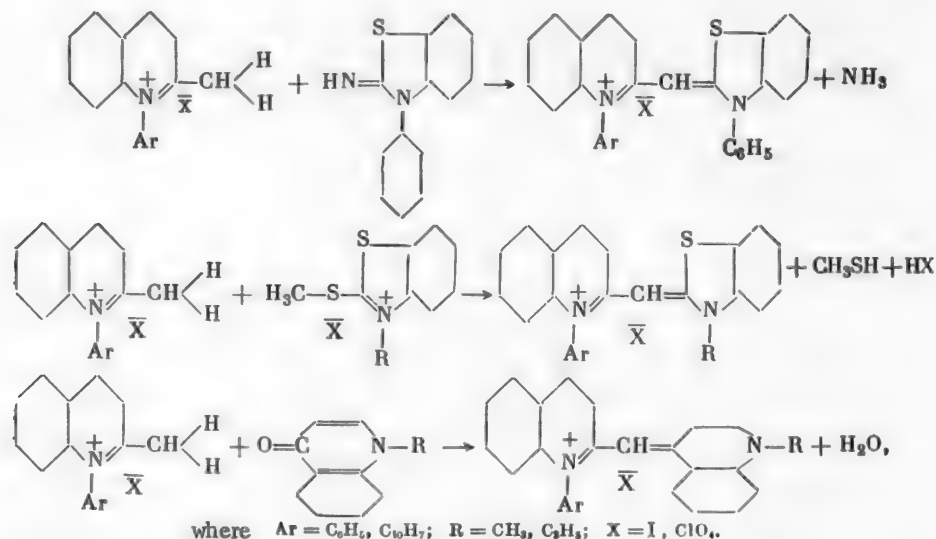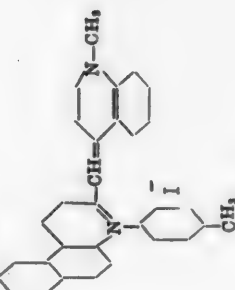
It was observed that the N-arylbenzoquinaldinium quaternary salts, when reacted with a thiazoloneimine under fusion conditions, form only quinothiacyanines, in accordance with the indicated scheme, whereas when

Expr. No.	Structural formula of dye	Absorption maximum (in mμ)	Melting point	Yield (in%)	Found element	Found amount (in %)	Empirical formula	Calculated element	Calculated amount (in %)
1		498	300°	47	Cl	6.61, 6.91	$C_{29}H_{21}O_4N_2SCl$	Cl	6.71
2		500	265	40	Cl	6.40, 6.55	$C_{31}H_{25}O_4N_2SCl$	Cl	6.36
3		501	237	43	I	20.70	$C_{29}H_{21}N_2SI$	I	20.93
4		502	200—201	30	I	20.37	$C_{30}H_{23}N_2SI$	I	20.45

Expt. No.	Structural formula of dye	Absorption maximum (in mμ)	Melting point	Yield (in %)	Found		Empirical formula	Calculated	
					element	amount (in %)		element	amount (in %)
5		510	210°	25	I	21.21	C₃₃H₃₃N₂S I	I	20.92
6		510	190	30	I	19.19	C₃₄H₃₅N₂SI	I	20.45
7		507	215	32	I	20.75	C₃₄H₃₅N₂S I	I	20.45

Expt. No.	Strucural formula of dye	Absorption maximum (in mµ)	Melting point	Yield (in %)	Found		Empirical formula	Calculated	
					element	amount (in %)		element	amount (in %)
8		494, 476	235—237	50	Cl	7.52	$C_{26}H_{19}O_4N_3SCl$	Cl	7.37
9		495	272—273	57	Cl	7.12	$C_{27}H_{19}O_4N_3SCl$	Cl	6.94
10		494	245—246	70	I	22.62, 22.50	$C_{26}H_{18}N_3SI$	I	22.72
11		500	240—241	45	I	21.84	$C_{30}H_{18}N_3SI$	I	22.17

Expt. No.	Structural formula of dye	Absorption maximum (in mμ)	Melting point	Yield (in%)	Found element	Found amount (in %)	Empirical formula	Calculated element	Calculated amount (in %)
12		506	276°	43	I	22.67	$C_{30}H_{25}N_2SI$	I	22.72
13		505	262—263	52	I	21.78	$C_{30}H_{25}N_2SI$	I	22.17
14		502	205—207	52	I	22.30	$C_{30}H_{25}N_2SI$	I	22.17

Expt. No.	Structural formula of dye	Absorption maximum (in mμ)	Melting point	Yield (in%)	Found element	Found amount (in %)	Empirical formula	Calculated element	Calculated amount (in %)
15		560	255°	45	Cl	7.43	$C_{26}H_{25}O_4N_2Cl$	Cl	7.69
16		567	171—172	40	Cl	7.38	$C_{29}H_{27}O_4N_2Cl$	Cl	7.25
17		563	188—189	25	Cl	6.81	$C_{30}H_{25}O_4N_2Cl$	Cl	6.93
18		570	196—197	60	I	22.58	$C_{31}H_{25}N_2I$	I	22.97

Expt. No.	Structural formula of dye	Absorption maximum (in mμ)	Melting point	Yield (in%)	Found element	Found amount (in %)	Empirical formula	Calculated element	Calculated amount (in %)
19		578	179—180°	73	Cl	6.62	$C_{30}H_{23}O_4N_2Cl$	Cl	6.93
20		579	190—191	53	Cl	6.57	$C_{31}H_{25}O_4N_2Cl$	Cl	6.75
21		578, 542	185—187	62	I	22.21	$C_{31}H_{25}N_2I$	I	22.40

the fusion is run with the salts of N-arylquinaldinium derivatives, the reaction also goes slightly in another direction with the formation of dyes of a different structure, where the linkage is in the 2,4 position, i.e., with the formation of isocyanines. Their formation was shown spectroscopically by taking the absorption curves of the mixed dyes and of the pure compounds (Figs. 1-4). These dyes were isolated by us using the technique of chromatographing on aluminum oxide, and then were identified by comparing with the isocyanines synthesized from the proper quaternary salts and quinolines in alkaline alcoholic medium [10]. In our study we synthesized 21 monomethinecyanines of unsymmetric structure (see table).

It was observed that the absorption maxima of the quinothiapseudocyanines with aromatic radicals are shifted toward longer wavelengths in the spectrum by 4-6 mμ when compared with similar cyanines, but have an ethyl radical at the nitrogen hetero atom of the benzothiazole ring. The absorption curves of the isomeric pseudocyanines with benzoquinoline rings have the absorption maxima shifted toward the red region of the spectrum when compared with the quinoline perichromams. The absorption curves of the isocyanines differ in character, and their maxima are shifted by 50-80 mμ toward longer wavelengths in the spectra, when compared with the thiocyanine analogs. Spectroscopic measurements reveal that the quinothiapseudocyanines with aromatic radicals on the nitrogen (when compared with alkyls), the isomeric cyanines with benzoquinoline perichromams, and also the isocyanines, have a higher energy level in the principal state, which is confirmed by the fact that they absorb light in the longer wavelength region of the spectrum.

EXPERIMENTAL

N-Phenylbenzothiazoloneimine was obtained by the bromination of unsymmetrical diphenylthiourea in chloroform solution, followed by subsequent treatment with ammonia according to the literature directions [11]. The arylquinaldinium quaternary salts were synthesized by condensing the proper secondary amines with paraldehyde or with vinyl butyl ether [12].

Dyes

1. (1-Phenyl-2-quinoline)(3-phenyl-2-benzothiazole)monomethinecyanine perchlorate. A mixture of 1 g of 1-phenylquinaldinium perchlorate and 0.7 g of 3-phenyl-3-iminobenzothiazole was fused in vacuo at 120-130° (30 mm) for 1.5 hours, with the evolution of ammonia bubbles. The dyes formed in this manner were isolated by two procedures.

a) The cooled dark-red melt was ground, dissolved with heating in 15 ml of alcohol-acetone mixture, and the product precipitated by the addition of hot water, in which connection the dye precipitated as a flocculent dark-red precipitate, which was filtered and then washed on the filter with alcohol until an orange color was obtained. Two recrystallizations from alcohol gave the dye as an orange product (m. p. 300°, absorption maximum at 498 mμ). From the alcohol filtrate we isolated the isocyanine (m. p. 180°) with absorption maximum at 564 mμ.

b) An alcohol-acetone solution of the reaction product was mixed with 100 ml of benzene. After standing for approximately 10 hours the dye deposited as lustrous orange crystals with m. p. 300°, while from the filtrate by chromatographing on aluminum oxide we isolated a dye that was obtained as fine dark crystals and had m. p. 180°. The absorption curves of the dyes are shown in Fig. 1.

2. (1-p-Tolyl-6-methyl-2-quinoline)(3-phenyl-2-benzothiazole)-monomethinecyanine perchlorate. A mixture of 3.4 g of 1-p-tolyl-6-methylquinaldinium perchlorate and 2.4 g of 3-phenyl-3-iminobenzothiazole was fused in vacuo at 135° (5 mm). The obtained melt was dissolved with heating in 100 ml of alcohol. Light-orange silky needles deposited on cooling, which after recrystallization from alcohol had m. p. 265°. From the filtrate, by chromatographing on aluminum oxide, we isolated a dye that in ethanol showed an absorption maximum at 572 mμ. The absorption curves of the dyes are shown in Fig. 2.

3. (1-α-Naphthyl-2-quinoline)(3-phenyl-2-benzothiazole)monomethinecyanine iodide. A mixture of 1 g of 1-α-naphthylquinaldinium iodide and 0.7 g of 3-phenyl-3-iminobenzothiazole was ground in a mortar, and then fused in vacuo at 110-120° (40 mm) for 1 hour until the evolution of ammonia ceased. The melt was dissolved in alcohol. Brown crystals of the dye deposited from the solution on long standing, which after recrystallization were obtained as lustrous dark-orange plates with m. p. 235-237°. The alcohol was distilled from

the filtrate on the water bath, while the residue in the flask was dissolved in a mixture of acetone and benzene (1:10), and the solution passed through a column containing aluminum oxide. Elution of the column either with an alcohol-benzene mixture (1:10) or with a mixture of alcohol, ethyl acetate and toluene (1:5:10) led to the isolation of a dye, obtained as dark crystals with m. p. 160°. The absorption curves are shown in Fig. 3.
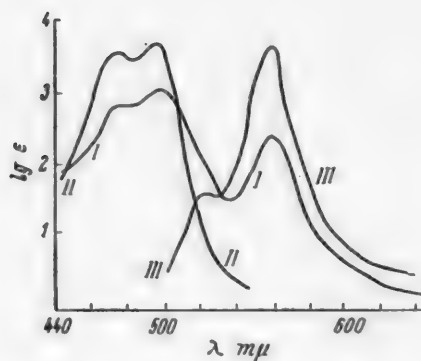

Fig. 1. Absorption curves of alcohol solutions of reaction mass (I), quinothia-pseudocyanine (II), and of dye isolated by chromatographing (III).
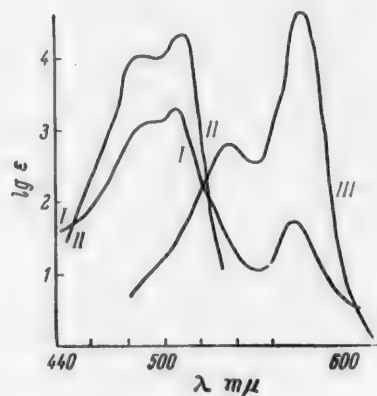

Fig. 2. Absorption curves of alcohol solutions of reaction mass (I), quinothia-pseudocyanine (II), and of dye isolated by chromatographing (III).

4. (1-α-Naphthyl-6-methyl-2-quinoline)(3-phenyl-2-benzothiazole)-monomethinecyanine iodide. A mixture of 1.2 g of 1-α-naphthyl-6-methylquinaldinium iodide and 0.75 g of 3-phenyl-3-iminobenzothiazole was ground in a mortar and then fused in vacuo at 115-120° (20 mm). The obtained melt was dissolved in alcohol and the solution filtered. Orange needles deposited, m. p. 200-201° (decomp.). Chromatographing gave the isocyanine with absorption maximum at 569 mμ. The absorption curves are shown in Fig. 4.
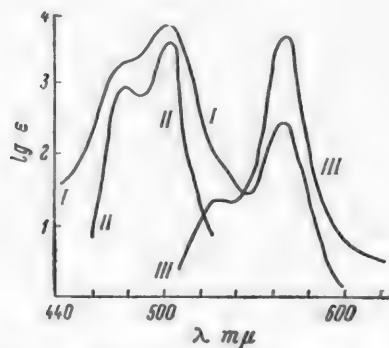

Fig. 3. Absorption curves of alcohol solutions of reaction mass (I), quinothia-pseudocyanine (II), and of dye isolated by chromatographing.
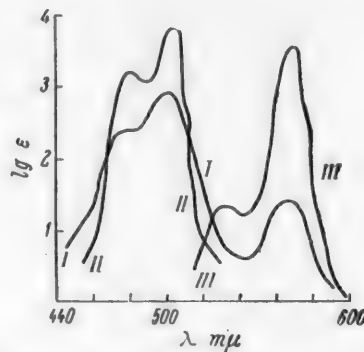

Fig. 4. Absorption curves of alcohol solutions of reaction mass (I), quinothia-pseudocyanine (II), and of dye isolated by chromatographing.

5. (1-Phenyl-5,6-benzo-2-quinoline)(3-phenyl-2-benzothiazole)-monomethinecyanine iodide. A mixture of 3.9 g of 1-phenyl-5,6-benzoquinaldinium iodide and 2.4 g of 3-phenyl-3-iminobenzothiazole was ground in a mortar and then fused in vacuo at 120-125° (20 mm) until ammonia ceased to evolve. The melt was extracted, ground, and dissolved in alcohol with heating. The dye precipitate, after recrystallization from alcohol, was obtained as needle crystals with m. p. 210° (decomp.).

6. (1-o-Tolyl-5,6-benzo-2-quinoline)(3-phenyl-2-benzothiazole)-monomethinecyanine iodide. A mixture of 1.2 g of 1-o-tolyl-5,6-benzoquinaldinium iodide and 0.75 g of 3-phenyl-3-iminobenzothiazole was ground in a mortar and then heated in vacuo at 120° for 1.5 hours. The melt was dissolved in alcohol. The dye was obtained as orange needles with m. p. 189-190°.

7. (1-p-Tolyl-5,6-benzo-2-quinoline)(3-phenyl-2-benzothiazole)-monomethinecyanine iodide. A mixture of 1.2 g of 1-p-tolyl-5,6-benzoquinaldinium iodide and 0.75 g of 3-phenylbenzothiazoloneimine was fused in vacuo. The mixture turned dark at 90° and melted, while a copious evolution of ammonia began at 110-115°. The reaction was run for 2.5 hours. The melt was dissolved in alcohol, and the dye deposited on standing overnight. Recrystallization gave the compound as lustrous red-orange needles with m. p. 214-215° (decomp.).

8. (1-Phenyl-2-quinoline)(3-ethyl-2-benzothiazole)-monomethinecyanine perchlorate. A mixture of 1.6 g of 1-phenylquinaldinium perchlorate, 1.5 g of methylmercaptobenzothiazole ethiodide and 0.75 g of anhydrous sodium acetate was heated in anhydrous alcohol for 5 minutes. The dye, obtained as an orange precipitate, had m. p. 235-237°.

9. (1-p-Tolyl-6-methyl-2-quinoline)(3-ethyl-2-benzothiazole)-monomethinecyanine perchlorate. A mixture of 0.28 g of p-tolyl-quinaldinium perchlorate, 0.25 g of methylmercaptobenzothiazole ethiodide and 0.12 g of anhydrous sodium acetate in 4 ml of anhydrous alcohol was refluxed for 10 minutes. The obtained crystals were filtered, washed with ether, and recrystallized. M. p. 272-273°.

10. (1-α-Naphthyl-2-quinoline)(3-ethyl-2-benzothiazole)-monomethinecyanine iodide. A mixture of 0.3 g of 1-α-naphthylquinaldinium iodide, 0.25 g of methylmercaptobenzothiazole ethiodide and 0.12 g of anhydrous sodium acetate in 3 ml of anhydrous alcohol was refluxed for 10 minutes in a paraffin bath. The next day the dark brown crystals were filtered and recrystallized from alcohol (m. p. 245-246°).

11. (1-α-Naphthyl-6-methyl-2-quinoline)(3-ethyl-2-benzothiazole)-monomethinecyanine iodide. A mixture of 0.3 g of 1-α-naphthyl-6-methylquinaldinium iodide, 0.25 g of 2-methylmercaptobenzothiazole ethiodide and 0.12 g of anhydrous sodium acetate in 4 ml of anhydrous alcohol was refluxed for 1 hour. The obtained dye precipitate was recrystallized from alcohol (m. p. 258-259°).

12. (1-Phenyl-5,6-benzo-2-quinoline)(3-ethyl-2-benzothiazole)-monomethinecyanine iodide. A mixture of 0.6 g of naphthoquinaldinium pheniodide, 0.5 g of methylmercaptobenzothiazole ethiodide and 0.25 g of sodium acetate in 5 ml of anhydrous alcohol was refluxed in a glycerin bath for 5 minutes. The obtained crystals were recrystallized from alcohol (m. p. 276°).

13. (1-o-Tolyl-5,6-benzo-2-quinoline)(3-ethyl-2-benzothiazole)-monomethinecyanine iodide. A mixture of 0.6 g of o-tolylbenzoquinaldinium iodide, 0.5 g of methylmercaptobenzothiazole ethiodide and 0.25 g of anhydrous sodium acetate in 6 ml of anhydrous alcohol was refluxed on the water bath for 15 minutes. The dye precipitate was filtered, washed with ether, and recrystallized from alcohol (m. p. 262°).

14. (1-p-Tolyl-5,6-benzo-2-quinoline)(3-ethyl-2-benzothiazole)-monomethinecyanine iodide. A mixture of 0.4 g of 1-p-tolylbenzoquinaldinium iodide, 0.3 g of 2-methylmercaptobenzothiazole ethiodide and 0.12 g of anhydrous sodium acetate was ground in a mortar and then dissolved with heating in 10 ml of anhydrous alcohol. The obtained orange precipitate of the dye was filtered, washed with ether and alcohol, and recrystallized (m. p. 205-207°).

15. (1-Phenyl-2-quinoline)(1-methyl-4-quinoline)-monomethinecyanine perchlorate. A mixture of 1.55 g of 1-phenylquinaldinium perchlorate and 2.6 g of quinoline methiodide was heated in 7 ml of anhydrous alcohol until complete solution was obtained. Then 1.12 g of 15% alcoholic KOH solution was added to the hot solution, and the mixture heated on the boiling water bath for 30 minutes. The dye was precipitated by adding water, and was recrystallized from alcohol (m. p. 203°).

16. (1-p-Tolyl-6-methyl-2-quinoline)(1-methyl-4 quinoline)-monomethinecyanine perchlorate. A mixture of 0.4 g of p-tolyl-2,6-dimethylquinolium perchlorate, 0.6 g of quinoline methiodide, 2 ml of alcoholic NaOH solution (5%) and 4 ml of anhydrous alcohol was refluxed for 15 minutes. The obtained crystals were filtered, and recrystallized from alcohol (m. p. 171-172°).

17. (1-α-Naphthyl-2-quinoline)(1-methyl-4-quinoline)-monomethinecyanine perchlorate. A mixture of 0.3 g of 1-α-naphthylquinaldinium perchlorate, 0.4 g of quinoline methiodide, 5 ml of alcohol and 2 ml of alcoholic NaOH solution (5%) was refluxed in a paraffin bath for 10 minutes. The obtained dye precipitate was filtered, converted to the perchlorate, and recrystallized (m. p. 188-189°).

18. (1-α-Naphthyl-6-methyl-2-quinoline)(1-methyl-4-quinoline)-monomethinecyanine iodide. A mixture of 0.3 g of 1-α-naphthyl-6-methylquinaldinium iodide, 0.39 g of quinoline methiodide, 2 ml of alcoholic NaOH solution (5%) and 4 ml of anhydrous alcohol was refluxed for 15 minutes. The deposit of dark-violet dye was filtered, washed with water and ether, and recrystallized from alcohol (m. p. 204-205°).

19. (1-Phenyl-5,6-benzo-2-quinoline)(1-methyl-4-quinoline)-monomethinecyanine perchlorate. A mixture of 0.3 g of 1-phenylbenzoquinaldinium iodide, 0.4 g of quinoline methiodide and 4 ml of anhydrous alcohol was heated, after which 1 ml of alcoholic KOH solution (5%) was added. The mixture was refluxed in a paraffin bath for 15 minutes. The obtained dye precipitate was filtered, washed, and recrystallized from alcohol (m. p. 179-180°).

20. (1-o-Tolyl-5,6-benzo-2-quinoline)(1-methyl-4-quinoline)-monomethinecyanine perchlorate. A mixture of 1 g of o-tolylbenzoquinaldinium iodide and 1.3 g of quinoline methiodide was dissolved with heating in 7 ml of anhydrous alcohol, and then 2.5 ml of alcoholic NaOH solution was added. The mixture was heated in a paraffin bath at 120° for 1 hour. The reaction product was treated with ether, dissolved in alcohol, and converted to the perchlorate. The obtained dye precipitate, after recrystallization, had m. p. 190-191°.

21. (1-p-Tolyl-5,6-benzo-2-quinoline)(1-ethyl-4-quinoline)-monomethinecyanine iodide. A mixture of 0.61 g of 1-p-tolyl-5,6-benzoquinaldinium iodide and 0.85 g of quinoline ethiodide was dissolved in 10 ml of anhydrous alcohol. Then 0.167 g of KOH as a 5% solution was added to the hot solution, after which the mixture was heated in a boiling water bath for 10 minutes. The next day the deposited dye was filtered, washed, and recrystallized from alcohol (m. p. 185-187°).

SUMMARY

1. Twenty-one monomethinequinocyanines of unsymmetric structure were synthesized and characterized.

2. The absorption maxima of the monomethinecyanines with aryl radicals on the nitrogen hetero atom are shifted toward the longer wavelength region of the spectrum (when compared with compounds having alkyl radicals).

3. Isomeric compounds having the phenylene group located in different positions of the molecule differ in color, which is reflected in their absorption maxima. The same is also true of the isocyanines and the quinothiapseudocyanines.

4. A methyl group in the principal perichrome gives a bathochromic shift of the absorption maximum of the molecule; when a radical is found on the nitrogen hetero atom the methyl group is practically without effect on the color.

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SYNTHETIC DYES

XIV. SYNTHESIS OF N-PHENYLLEPIDINIUM PERCHLORATE AND SOME OF ITS TRANSFORMATIONS

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Lepidine derivatives have received comparatively less study than either quinoline or quinaldine derivatives, which can be explained both by a lack of satisfactory synthesis methods and by their lower reactivity. Beyer [1], in expanding the Doebner - von Miller reaction, was the first to synthesize lepidine in low yield by the cyclization of aniline with acetone and formaldehyde in the presence of hydrochloric acid. B. I. Ardashev and B. A. Tertov, using acylated amines [2], were able to obtain higher yields of the lepidines. In [3-7] it was shown that it is possible to synthesize N-arylquaternary salts of quinoline, quinaldine and lepidine by the cyclization of secondary aromatic amines with aldehydes, ketones and vinyl ethers in acid medium.

Applying the Beyer reaction to diphenylamine, we succeeded in obtaining the onium salt, N-phenyllepidinium perchlorate (I), and studied some of its transformations. The reaction went in accordance with the scheme:
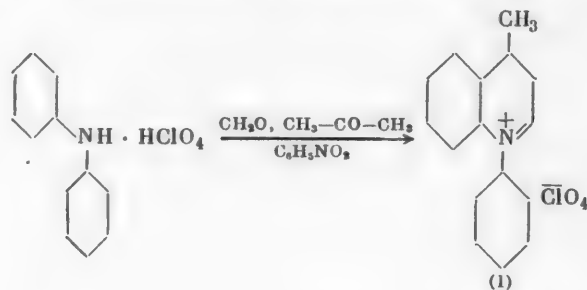
The obtained quaternary salt was condensed with various compounds to yield cyanine dyes. The heating of salt (I) with orthoformic ester in pyridine led to the isolation of the symmetrical dye (II) [8, 9]:
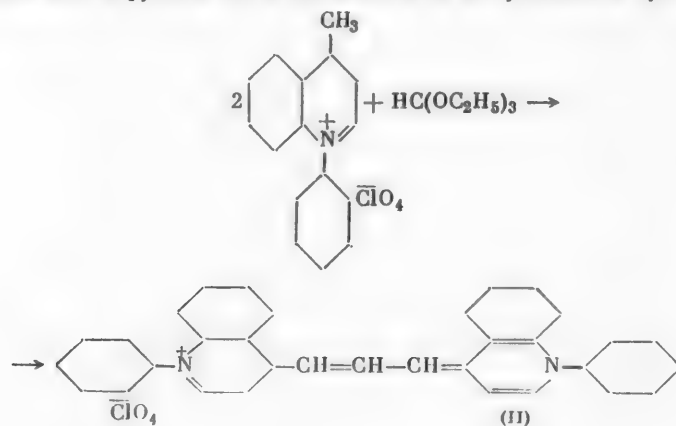
with maximum absorption at 718 mµ. Consequently, the phenyl derivative absorbs in the longer wavelength region of the spectrum when compared with the ethyl derivative (710 mµ). The condensation of N-phenyl-lepidinium perchlorate with N-ethylquinolinium iodide in the presence of alcoholic caustic gave the mono-methine dye (III) [10], with maximum absorption at 592 mµ.

(III)

(IV)
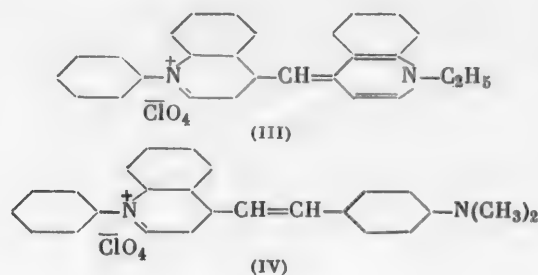
Reaction of the salt with p-dimethylaminobenzaldehyde by heating in acetic anhydride went with the formation of the styryl derivative (IV) [11], with maximum absorption at 578 mµ. The absorption curves were taken in alcohol, using an automatically recording SF-2M spectrophotometer.

EXPERIMENTAL

N-Phenyllepidinium perchlorate (I). Into a three-necked flask, fitted with a mechanical stirrer, reflux condenser and dropping funnel, were charged 85 g of diphenylamine, 100 ml of water, 140 ml of perchloric acid (30%), 75 ml of acetone and 40 ml of nitrobenzene. The flask was then heated in a boiling water bath, the stirrer turned on after 30 minutes, and 50 ml of formalin (30%) added in small portions from the dropping funnel in 30 minutes. Ice water was run constantly through the condenser during experiment. When all of the formalin had been added, the heating with stirring was continued for 7 hours. Then the supernatant water layer was decanted from the heavy brown tar on the bottom of the flask, after which the tar was treated repeatedly with 10 liters of boiling water. The water extracts were combined, boiled with activated carbon to decolorize and remove nitrobenzene, filtered, and evaporated in a porcelain dish on the water bath until the quaternary salt began to crystallize. The long needle-like crystals that deposited on standing overnight were filtered and re-crystallized twice from alcohol. The salt had m. p. 173-174°. Yield 24 g (15%). The salt is soluble in water, alcohol, acetone, chloroform, and pyridine, is difficultly soluble in benzene and toluene, and is practically in-soluble in ether and carbon tetrachloride.

Found %: Cl 11.30, 11.18. $C_{16}H_{14}O_4NCl$. Calculated %: Cl 11.09.

Bis(1-phenyl-4-quinoline)trimethinecyanine perchlorate. A mixture of 5 g of phenyllepidinium per-chlorate, 10 ml of dry pyridine and 1.5 ml of orthoformic ester was heated in a paraffin bath at gentle boil for 1 hour. The reaction mass gradually assumed a green color. The obtained dye was precipitated with ether, filtered, and washed with ether until all of the pyridine was removed. Recrystallization from acetone gave 2.25 g (56%) of the dye. The dye was obtained as green needle crystals with a metallic luster, and had m. p. 253-255°. The compound is difficultly soluble in alcohols, slightly more soluble in acetone, chloroform, acetic anhydride and pyridine, and practically insoluble in water, ether, dioxane, carbon tetrachloride, benzene and toluene.

Found %: Cl 6.30, 6.52. $C_{33}H_{25}O_4N_2Cl$. Calculated %: Cl 6.46.

(1-Phenyl-4-quinoline)(1-ethyl-4-quinoline)monomethinecyanine perchlorate (III). Into a flask were charged 4 g of phenyllepidinium perchlorate, 7 g of 1-ethylquinolinium iodide and 80 ml of anhydrous alcohol, and the whole heated in a boiling water bath until all of the crystals had dissolved. Then 16 ml of alcoholic KOH solution (5%) was added with vigorous shaking. After this the reaction mass was heated at gentle boil for 15 minutes, and here the mass assumed a blue color. The obtained dye was precipitated with water, filtered, and washed with a small amount of alcohol and ether. Yield 5 g (83.3%). The dye after recrystallization from alcohol was obtained as fine needle crystals with a bronze luster, m. p. 145-147°. The compound is readily

soluble in alcohol, acetone, pyridine, chloroform and acetic anhydride, is difficultly soluble in benzene and water, and is practically insoluble in carbon tetrachloride and ether. An alcohol solution of the compound is colored blue.

Found %: Cl 7.26, 7.38. $C_{27}H_{23}O_4N_2Cl$. Calculated %: Cl 7.47.

(1-Phenyl-4-quinoline)-p-dimethylaminostyryl perchlorate. A mixture of 3.5 g of phenyllepidinium perchlorate, 2 g of p-dimethylaminobenzaldehyde and 15 ml of acetic anhydride was heated at the boil in a paraffin bath for 15 minutes. The reaction mass gradually assumed a violet color. Standing for 24 hours led to the deposition of green needle crystals with a metallic luster, which were filtered, and washed with alcohol and ether. Yield 3.5 g (70%), m. p. 241°. The dye is readily soluble in acetic anhydride, pyridine, acetone and chloroform, difficultly soluble in alcohol, and practically insoluble in hydrocarbons, carbon tetrachloride, water and ether.

Found %: Cl 7.82, 7.74. $C_{26}H_{23}O_4N_2Cl$. Calculated %: Cl 7.86.

SUMMARY

1. The previously unknown quaternary salt, N-phenyllepidinium perchlorate, was synthesized by the cyclization of diphenylamine with formaldehyde and acetone in the presence of perchloric acid.

2. Some new dyes were obtained from the indicated salt, and their properties described.

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SYNTHESIS OF SOME NITRO AND AMINO DERIVATIVES OF
DIPHENYLMETHANE AND 1,2-DIPHENYLETHANE

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For some investigations being conducted in our laboratory it proved necessary to obtain 4-amino-4'-nitrodiphenylamine (I) and the corresponding amino nitro derivative of 1,2-diphenylethane (bibenzyl) (II).
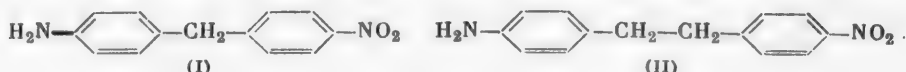
We decided to synthesize both compounds by the partial reduction of the corresponding 4,4'-dinitro derivatives. In selecting the reduction conditions it must be kept in mind that the alkali sulfides, usually used in such cases, are not suitable here, since they can cause undesirable changes in the methylene groups of the indicated compounds [1].

The use of phenylhydrazine for this purpose proved successful: here we obtained (I), melting at 98°, and (II), with m. p. 138°.* The experimental data accumulated in our laboratory on the partial reduction of various aromatic dinitro compounds, in which the nitro groups are found in different benzene rings, frequently not directly connected, indicate that this reducing agent, reacting with the nitro product according to the scheme

$$ArNO_2 + 3C_6H_5NHNH_2 \longrightarrow ArNH_2 + 3C_6H_6 + 2H_2O + 3N_2,$$

is one of the better and practically unequalled agents for the partial reduction of complex polynitro compounds. The reaction with phenylhydrazine is conveniently run in inert solvents (xylene, halogenated benzene derivatives, biphenyl, etc.). The less reactive the nitro compound, the higher the boiling point of the solvent needed. Here it is even possible to use phenylhydrazine itself [4]. The reduction technique using phenylhydrazine is simple and is described below.

To prove the structure of the products (I) and (II), they were reduced to the known 4,4'-diamino derivatives of diphenylmethane and bibenzyl. In addition, (II) was deaminated to give the known 4-nitrobibenzyl, which in turn was reduced to the known 4-aminobibenzyl. The last synthesis is a new and convenient way of obtaining this quite difficultly accessible amino derivative of bibenzyl.

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* In their properties, both compounds do not resemble the high melting products obtained by R. S. Tsekhanskii [2] and by G. V. Alekseeva [3] when they treated the 4,4'-dinitro derivatives of diphenylmethane and bibenzyl with alkali sulfides, to which the indicated authors apparently, as follows from our earlier presented data [1], and also in this paper, erroneously assigned the structures (I) and (II).

4-Amino-4'-nitrodiphenylmethane. A mixture of 1.5 g of 4,4'-dinitrodiphenylmethane [1], 15 g of p-dichlorobenzene and 2 ml of phenylhydrazine in a test tube fitted with an air reflux condenser was heated, with periodic shaking, in a paraffin bath (thermometer in the bath). The nitro compound goes into solution after the p-chlorobenzene has melted, and the evolution of nitrogen is observed above 110-120°, indicating that reduction is taking place. The reaction course was checked by the rate with which gas bubbles passed through a glass capillary, one end of which was connected through a rubber stopper with the top of the condenser, and the other end was immersed in a test tube containing approximately 0.5 ml of water. As the reaction slowed up (nitrogen ceased to evolve) the temperature was raised slowly, and this revived the reaction. In this manner, the bath temperature was raised to 170°, and the mixture kept at 170° for 20-30 minutes, at the end of which time the evolution of nitrogen had ceased. The reduction lasted about 4 hours. After cooling, the crystalline mass was dissolved in benzene, and the benzene solution was shaken vigorously with 40 ml of 10% sulfuric acid. Here the amine separated as the sulfate, which was suction-filtered and washed on the filter with benzene. The yield of salt was 0.9 g (56%); it was recrystallized twice from 10% sulfuric acid (the first time using activated carbon). To obtain the free base, the sulfate was triturated with concentrated aqueous ammonia and the obtained product was washed with water; after recrystallization from methyl alcohol, m. p. 98°. The amine was obtained as golden yellow crystals, insoluble in water and readily soluble in the common organic solvents.

Found %: NH_2 [5] 6.88, 6.95. $C_{13}H_{12}O_2N_2$. Calculated %: NH_2 7.02.

Reduction of 4-amino-4'-nitrodiphenylmethane and 4,4'-diaminodiphenylmethane. To a solution of 0.2 g of 4-amino-4'-nitrodiphenylmethane in 10 ml of hot methyl alcohol was added 0.3 ml of hydrazine hydrate, followed by the gradual addition of Raney nickel powder, observing all of the operational procedures described earlier [6, 7]. At reaction end (nitrogen had ceased to evolve) the liquid was filtered, and then evaporated to a small volume. The residue on cooling deposited a white crystalline substance, which after recrystallization from methyl alcohol had m. p. 93°, which agrees with [8]. The mixed melting point with an authentic specimen of this amine was not depressed.

4-Amino-4'-nitrobibenzyl was obtained in the same manner as 4-amino-4'-nitrodiphenylmethane (2.4 g of 4,4'-dinitrobibenzyl,** 24 g of p-dichlorobenzene and 2.8 g of phenylhydrazine). The reduction lasted about 6 hours. The yield of amine sulfate was 2 g (78%). The free base, after recrystallization from methyl alcohol, had m. p. 138°. In its properties this compound closely resembles 4-amino-4'-nitrodiphenylmethane; its crystals have an orange-yellow color.

Found %: NH_2 [5] .6.49, 6.51. $C_{14}H_{14}O_2N_2$. Calculated %: NH_2 6.61.

Reduction of 4-amino-4'-nitrobibenzyl to 4,4'-diaminobibenzyl. This operation was similar to the reduction of 4-amino-4'-nitrodiphenylmethane. The melting point of the obtained 4,4'-diaminobibenzyl, purified by recrystallization from methyl alcohol, was 135°, which agrees with [11].

4-Nitrobibenzyl. A solution of 2.4 g of 4-amino-4'-nitrobibenzyl in a mixture of 40 ml of water and 6 ml of concentrated hydrochloric acid was prepared by warming. Rapid cooling of the solution in a mixture of salt and ice gave a finely crystalline precipitate of the hydrochloride, which was then treated in drops (with vigorous stirring) with a cooled to 0° solution of 0.8 g of sodium nitrite in 8 ml of water. Here the precipitate gradually dissolved. The diazo solution obtained in this manner was then added in small portions, with stirring, to an ice-cooled mixture composed of 20 g of potassium hypophosphite and 20 ml of concentrated hydrochloric acid. The loosely stoppered flask was allowed to stand for several hours with cooling, and then for three days at room temperature. The obtained tarry deposit was separated from the liquid and washed with water. After drying in a vacuum-desiccator over anhydrous calcium chloride the product weighed 2.g. Repeated recrystallization

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* Students G. V. Aref'eva and D. N. Medved' assisted in the experimental portion of the work.
** Whether prepared by the nitration of bibenzyl with nitric acid in acetic anhydride [9] or by the oxidation of p-nitrotoluene with atmospheric oxygen in aqueous alcoholic caustic solution [10], the products proved to be equally suitable.

from methyl alcohol (several times at the start with activated carbon) gave a small amount of substance with m. p. 70-71°, which agrees with [12].

4-Aminobibenzyl. To the crude deamination product obtained from 2.4 g of 4-amino-4'-nitrobibenzyl, after washing with water (drying is not obligatory here), was added 50 ml of methyl alcohol, and this mixture was heated under reflux until most of the deamination product had gone into solution. The hot mixture was then treated with 2 ml of hydrazine hydrate, and the reduction with Raney nickel was run in the same manner as indicated above. When reaction had ceased, the hot solution was again treated with 2 ml of hydrazine hydrate and fresh nickel catalyst. After this, when the evolution of nitrogen had again ceased, the solution, which was not permitted to cool, was filtered, treated with activated carbon, and the alcohol removed completely by evaporation. The reaction product was extracted from the oily residue by treating with dilute (1 : 2) hydrochloric acid at the boil. The extract on cooling deposited white crystals of 4-aminobibenzyl hydrochloride. Yield 0.5 g (21%, based on 4-amino-4' nitrobibenzyl). The salt was again recrystallized from dilute (1 : 2) hydrochloric acid (using activated carbon). Treatment of the salt with aqueous ammonia gave the free base, which after recrystallization from petroleum ether had m. p. 49° (literature [12]: 48°).

SUMMARY

1. 4-Amino-4' nitrodiphenylmethane and 4-amino-4'-nitrobibenzyl were synthesized.

2. Some new methods were proposed for the synthesis of 4-nitrobibenzyl and 4-aminobibenzyl.

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2-TRIFLUOROMETHYLNAPHTHALENE AND ITS DERIVATIVES

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Trifluoromethyl derivatives of naphthalene have remained completely unstudied. Mention of the synthesis of 1-trifluoromethylnaphthalene is made only in the American patent [1]; however, neither the constants nor the method of preparation of either the final product or the starting 1-trichloromethylnaphthalene are given in the patent.

Trichloromethyl derivatives of naphthalene are difficultly available compounds, since the chlorination of methylnaphthalenes yields a mixture of substances containing both side-chain and nuclear halogen [2].

It was shown by A. N. Nesmeyanov and co-workers [3] that the thermal decomposition of copper trichloro-acetate in excess naphthalene yields α-trichloromethylnaphthalene. However, the α-trichloromethylnaphthalene was not isolated, and instead was identified as α-naphthoic acid. Consequently, we decided to use as starting materials for the preparation of trifluoromethyl compounds of the naphthalene series the o-chlorotrichloromethyl derivatives of naphthalene, obtained from the corresponding o-hydroxynaphthoic acids by treatment with phosphorus pentachloride. Of the three o-hydroxynaphthoic acids of naphthalene only the 1-hydroxy-2-naphthoic acid was converted by Wolffenstein to 1-chloro-2-trichloromethylnaphthalene [4], the yield of which was not indicated. In the case of 2-hydroxy-1-naphthoic [5] and 2-hydroxy-3-naphthoic [6] acids the authors were unable to isolate the trichloromethyl derivatives of naphthalene, and they were identified only as the corresponding o-chloronaphthoic acids.

We repeated Wolffenstein's experiments and found that it is possible to obtain 1-chloro-2-trichloromethyl-naphthalene from 1-hydroxy-2-naphthoic acid in 35% yield.

An attempt to substitute fluorine for chlorine in the trichloromethyl group of 1-chloro-2-trichloromethyl-naphthalene by heating with antimony trifluoride in the presence of antimony pentachloride, and without it, proved unsuccessful. As a result of the fluorination, we obtained a hard resinous mass from which we were unable to isolate any pure compounds. The fluorination was also run in solvents. The most suitable for this purpose proved to be chlorobenzene, and using it we obtained 1-chloro-2-trifluoromethylnaphthalene in 90% yield.

The heating of 1-chloro-2-trifluoromethylnaphthalene with cuprous cyanide in the presence of pyridine led to its conversion to the nitrile of 2-trifluoromethyl-1-naphthoic acid. The latter was converted to the amide, which was converted to 2-trifluoromethyl-1-naphthoic acid, and also, by Hofmann rearrangement, to 1-amino-2-trifluoromethylnaphthalene. The general scheme of the transformations is shown below.
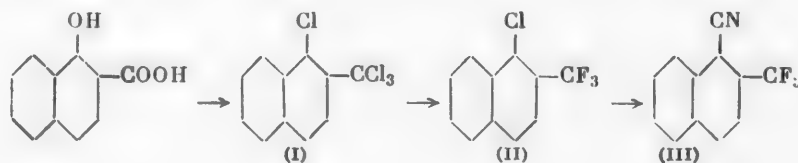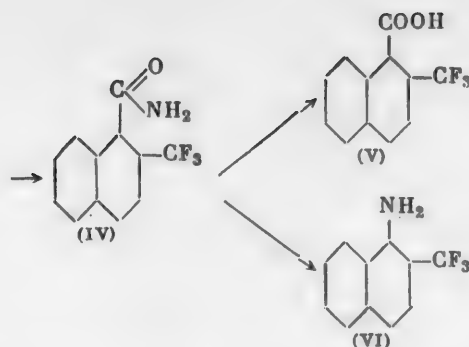
In running the Hofmann reaction it was found that heating the amide (IV) with sodium hypobromite for 45 minutes gives the amine (VI) in a total yield of only 15%. Substantial amounts of a compound identified as 1-amino-2-naphthoic acid were isolated from the alkaline solution. Apparently, the Hofmann reaction goes smoothly. However, the 1-amino-2-trifluoromethylnaphthalene that is formed here is easily hydrolyzed when heated in alkaline medium. We were able to confirm this by a separate experiment. For this reason, we ran the Hofmann reaction in such manner that the amine was removed from the reaction sphere as fast as it was formed by steam-distillation; in this way we were able to increase the yield of the amine to 61%. Consequently, we established that the trifluoromethyl group in 1-amino-2-trifluoromethylnaphthalene is unstable toward aqueous caustic solution, the same as is true of the o- and p-trifluoromethylphenols [7].

Both amine (VI) and α-naphthylamine [8] were diazotized and then coupled with dimethylaniline to give dyes of the (A) type.
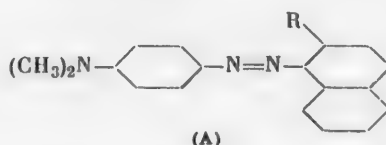
As can be seen from the Table, the introduction of the trifluoromethyl group into the dye molecule (A) shifts its absorption maximum toward shorter wavelengths, both in neutral and in acid solutions. It is interesting that the extinctions of these two dyes in acid medium are reduced to the same degree. This is apparently due to the substantial steric hindrance created by the presence of the second benzene ring, preventing the proton from adding to the nitrogen atom of the azo group. For this reason, the presence of the trifluoromethyl group is practically without effect on the extinction in the given case.

R	λ max in alcohol (in mμ)	$\varepsilon \cdot 10^{-4}$	λ max in alcohol+HCl* (in mμ)	$\varepsilon \cdot 10^{-4}$
H	431	2.86	538	0.29
CF$_3$	408	2.51	465	0.31

Amine (VI) diazotizes with much greater difficulty than does α-naphthylamine. Attempts to obtain 2-trifluoromethylnaphthalene by the deamination of amine (VI) proved quite unsuccessful; for this reason, we investigated the decarboxylation of 2-trifluoromethyl-1-naphthoic acid. In quinoline solution, in the presence of copper powder, the decarboxylation of acid (V) gives β-trifluoromethylnaphthalene in nearly quantitative yield.

EXPERIMENTAL

1-Chloro-2-trichloromethylnaphthalene was obtained by the Wolffenstein procedure [1] from 1-hydroxy-2-naphthoic acid in 35% yield.

* Two volumes of EtOH and one volume of HCl (d 1.19).

1-Chloro-2-trifluoromethylnaphthalene. Sublimed antimony trichloride (31.0 g) and 60 ml of dry chlorobenzene were mixed. About 10-12 ml of chlorobenzene was distilled off in order to remove all traces of moisture, and then 28.0 g of dry 1-chloro-2-trichloromethylnaphthalene was added. Stirring with gentle boil was maintained for 9 hours, after which the mixture was cooled, 100 ml of 20% hydrochloric acid was added, and the product was extracted with ether. The ether-chlorobenzene solution was washed with hydrochloric acid until all antimony salts were removed, then with 5% sodium carbonate solution, finally with water, and dried. The ether and chlorobenzene were vacuum-distilled using a water-jet pump, and the residue was steam-distilled. The yield of 1-chloro-2-trifluoromethylnaphthalene was 20.7 g (90%). M. p. 59-61°. Recrystallization from 85% methanol gave the compound as tablets with m. p. 62.5°. Readily soluble in benzene, ether, acetone, and petroleum ether.

Found %: Cl 15.63, 15.68. $C_{11}H_6ClF_3$. Calculated %: Cl 15.37.

2-Trifluoromethyl-1-naphthonitrile. A well-mixed mixture of 1.73 g of 1-chloro-2-trifluoromethylnaphthalene and 0.81 g of cuprous cyanide was placed in a Carius tube and then 0.7 ml of dry pyridine was added. The sealed tube was heated for 24 hours at 250°, after which the tube contents were steam-distilled. Yield 1.18 g (71.5%). M. p. 81-83°. Recrystallized from methanol. Prisms with m. p. 83-84°. Readily soluble in benzene, ether and acetone.

Found %: N 6.06, 6.10. $C_{12}H_6NF_3$. Calculated %: N 6.33.

2-Trifluoromethyl-1-naphthamide. For reaction we took a mixture of 6.9 g of 2-trifluoromethyl-1-naphthonitrile, 60 ml of alcohol, 25 ml of 25-30% hydrogen peroxide and 3 ml of 20% sodium hydroxide. The mixture was heated to 40°, 5 ml of hydrogen peroxide was added, and the mixture heated for another 3 hours at 60°, after which another 5 ml of hydrogen peroxide was added, and the whole allowed to stand overnight. The next day, using the water-jet pump, the mixture was evaporated in vacuo, with slight warming, nearly to dryness, after which the obtained crystals of the amide were filtered, washed with water, and dried. Yield 7.05 g (95%). M. p. 172-173°. Recrystallized from 70% methanol; needles with m. p. 174°. Readily soluble in acetone, benzene and alcohol.

Found %: N 5.78, 5.91. $C_{12}H_8ONF_3$. Calculated %: N 5.86.

1-Amino-2-trifluoromethylnaphthalene. 2-Trifluoromethyl-1-naphthamide (5.63 g) was dissolved in sodium hypobromite solution prepared from 5.65 g of NaOH and 1.4 ml of bromine in 45 ml of water. The solution was heated on the water bath and at the same time the amine was removed by steam-distillation. The distillate was extracted with ether and the ether extract was dried. The ether was distilled off. The yield of amine was 3.0 g (61%). The alkaline solution remaining in the flask from the steam distillation was acidified, and the product was filtered to give 1.7 g (38%) of 1-amino-2-naphthoic acid. The amine was recrystallized from petroleum ether. Prisms with m. p. 106°. Readily soluble in benzene, ether, acetone and alcohol.

Found %: N 6.49, 6.67. $C_{11}H_8NF_3$. Calculated %: N 6.63.

Alkaline hydrolysis of 1-amino-2-trifluoromethylnaphthalene. To a mixture of 0.1 g of the amine, 0.4 g of NaOH and 4 ml of water was added 2 ml of alcohol, and the whole was heated for 0.5 hour on the boiling water bath. The mixture was diluted with water, and then acidified. We obtained 0.07 g of 1-amino-2-naphthoic acid with m. p. 200-202° (with decomp.). The literature gives m. p. 205° (with decomp.) [9].

2-Trifluoromethyl-1-naphthoic acid. 2-Trifluoromethyl-1-naphthamide (2.39 g) was dissolved in a mixture of 10 ml of water and 5 ml of concentrated sulfuric acid. The solution was heated to 95-100°, and then 1.6 g of sodium nitrite was added with stirring. After cooling, the reaction was diluted with water and the product extracted with ether. The ether solution was treated with 10% NaOH solution, and the alkaline extract was acidified with concentrated hydrochloric acid, followed by filtration of the 2-trifluoromethyl-1-naphthoic acid. Yield 2.2 g (92%). M. p. 165-166°. Recrystallized from 50% methyl alcohol. Needles with m. p. 167-168°. Readily soluble in alcohol, acetone, and ether.

Found %: F 23.91, 24.09. $C_{12}H_7O_2F_3$. Calculated %: F 23.75.

2-Trifluoromethyl-1-naphthyl-4-dimethylaminoazobenzene. A suspension of 0.42 g of 1-amino-2-trifluoromethylnaphthalene in 12 ml of 20% hydrochloric acid was diazotized at 0° with a solution of 0.15 g of sodium nitrite in 2 ml of water. The excess hydrochloric acid was neutralized with sodium acetate, the

solution filtered, and the filtrate treated with a solution of 0.25 g of dimethylaniline in 2 ml of acetic acid. The next day, the dye was filtered, followed by recrystallization from alcohol. Black needles. M. p. 166-167°.

Found %: N 11.88, 12.25. $C_{19}H_{16}N_3F_3$. Calculated %: N 12.24.

2-Trifluoromethylnaphthalene. A mixture of 1.2 g of 2-trifluoromethyl-1-naphthoic acid, 10 ml of quinoline and 0.1 g of copper powder was heated for 1.25 hours at 250°. The reaction after cooling was treated with an excess of 20% hydrochloric acid, and then extracted with ether. The ether solution was washed with water, then with 10% sodium carbonate solution, and dried. The ether was distilled off, and the residue was worked up to give 0.95 g (97%) of 2-trifluoromethylnaphthalene with m. p. 65-66°. Recrystallized from 70% methanol. Tiny needles with m. p. 67.5°. Soluble in benzene, acetone, ether, alcohol, and petroleum ether.

Found %: F 29.27, 29.38. $C_{11}H_7F_3$. Calculated %: F 29.05.

SUMMARY

The synthesis of 2-trifluoromethylnaphthalene was described, as was also the synthesis of its 1-derivatives: chloro-, amino-, carboxylic acid, and the nitrile and amide of the latter. It was shown that the trifluoromethyl group in 1-amino-2-trifluoromethylnaphthalene is unstable toward aqueous caustic solutions. 2-Trifluoromethyl-1-naphthyl-4-dimethylaminoazobenzene was synthesized, and both its absorption maximum and extinction in alcohol and alcohol-hydrochloric acid solutions were determined.

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SYNTHESIS OF NITRO DERIVATIVES OF ω-CHLOROSTYRENE

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Both the p- and m-nitrophenyl(chloromethyl)carbinols have recently become readily available compounds [1, 2]. We attempted to use these compounds to synthesize the corresponding nitro derivatives of ω-chlorostyrene by replacing the hydroxyl group by chlorine, followed by the cleavage of hydrogen chloride, as shown in Scheme A.
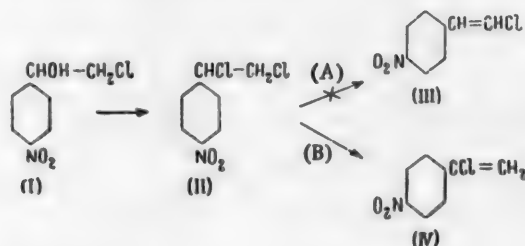

However, when we attempted to replace the hydroxyl group in (I) by chlorine using thionyl chloride we obtained, instead of the desired (II), the meso form of the known [3] α,α'-di-(p-nitrophenyl)-β,β'-dichloro-diethyl ether (V) with m. p. 129°.
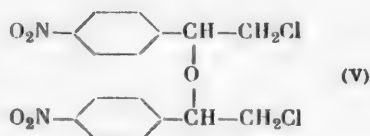
When reacted with phosphorus pentachloride, (I) is converted smoothly to (II), which reacts with alcoholic triethylamine solution according to Scheme B. The reaction of other alkaline agents with (II), like aqueous alcoholic caustic or pyridine, also leads to product (IV), but in lower yield.

The structure of (IV) was shown by the counter synthesis [4], according to the scheme
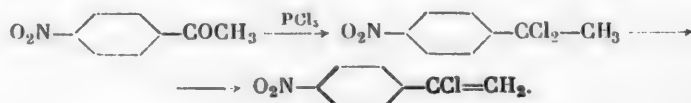
The mixed melting point of these two compounds was not depressed.

(m-Nitrophenyl) (chloromethyl) carbinol (VI) behaves in a similar manner in these reactions. The reaction of (VI) with thionyl chloride gave α,α'-di-(m-nitrophenyl)-β,β'-dichlorodiethyl ether (VII). By analogy with the p- isomer (V), we assigned it the structure of the meso form. When hydrogen chloride is cleaved from the compound, using alcoholic triethylamine solution, a noncrystallizing oil is obtained, capable of being vacuum-

distilled. In contrast to it, the earlier described [5] ω-nitro-m-chlorostyrene is a solid with m. p. 83°. On this basis, and by analogy with the p-isomer, the obtained compound should have the structure of m-nitro-α-chlorostyrene (IX).

We also synthesized the previously unknown 3,5-dinitrophenyl-(X) and 2,4-dinitrophenyl-(XI) (chloromethyl)carbinols by the nitration of the nitrates of the corresponding m- and p-nitrophenyl (chloromethyl)-carbinols, followed by saponification.

(X) (XI)
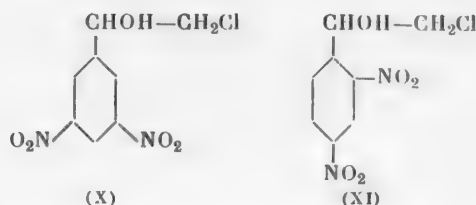
The structure of the nitrates of (X) and (XI) was shown by oxidation with nitric acid to the corresponding dinitrobenzoic acids.

As is known, the saponification of organic nitrates in either neutral or alkaline medium yields, besides carbinols, also ethylenic hydrocarbons, carbonyl derivatives and nitrogen oxides as by-products [6]. For this reason, we ran the saponification of the organic nitrates obtained by us in strongly acid medium (either 60% sulfuric acid or 27% nitric acid) in the presence of urea. Here the formation of by-products was reduced to a minimum.

The reaction of (3,5-dinitrophenyl)(chloromethyl)carbinol with phosphorus pentachloride gave the dichloride (XII), and this on cleaving hydrogen chloride gave 3,5-dinitro-α-chlorostyrene (XIII).

2,4-Dinitrostyrene oxide was obtained by the cleavage of hydrogen chloride from (2,4-dinitrophenyl)(chloromethyl)carbinol.

An attempt was made to obtain p-nitro-ω-chlorostyrene by the removal of water from (p-nitrophenyl)(chloromethyl)carbinol. Heating the carbinol with anhydrous zinc chloride or with potassium bisulfate gave (III) in 10-15% yield. M. p. 128°. (The p-nitro-ω-chlorostyrene described in the literature has the same melting point; it was obtained in 5-15% yield by reacting p-nitrocinnamic acid with sodium hypochlorite [5]). We were able to obtain a much better yield by heating carbinol (I) with phosphorus pentoxide at 100°. The yield of (III) was as high as 47%. In addition, compound (XIV) (racemate) was isolated from this reaction in about 4% yield. (XIV) has m. p. 172°, the same as that given in [3].

In a similar manner, the removal of water from the corresponding carbinols using phosphorus pentoxide gave 3-nitro-ω-chlorostyrene (XV) and 3,5-dinitro-ω-chlorostyrene (XVI). In the last case, we obtained α,α'-di(3,5-dinitrophenyl)-β,β'-dichlorodiethyl ether as by-product, to which, by analogy with the p-isomer, we assign the structure of (XVII).

(XIV) (XVII)
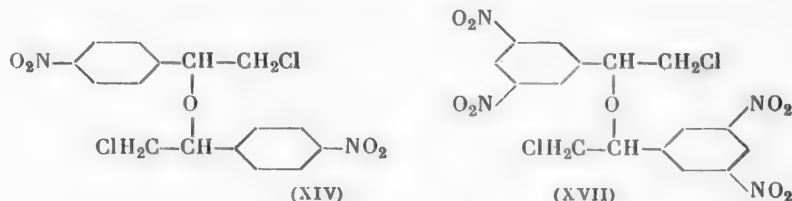
As yet, we have been unable to obtain 2,4-dinitro-ω-chlorostyrene from (2,4-dinitrophenyl)(chloromethyl) carbinol, since the removal of water from the latter, using either potassium bisulfate or phosphorus pentoxide at various temperatures, either resulted in tarring or the compound was completely unreactive.

p-Nitro-ω-chlorostyrene is the vinylene homolog of p-nitrochlorobenzene, and for this reason, should possess a labile halogen. We reacted the compound with alcoholic sodium sulfide solution and obtained bis(β-4-nitrophenylvinyl) sulfide (XVIII).

(XVIII)
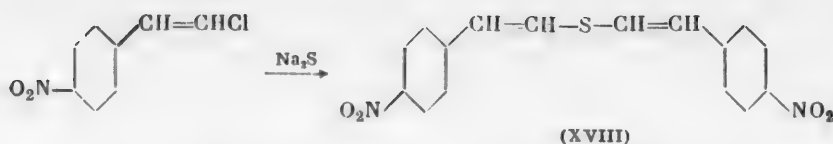
Oxidation of the sulfide with hydrogen peroxide gave the sulfone. As is known, the double bond is not attacked when unsaturated sulfides are oxidized with hydrogen peroxide [7], and consequently the sulfone obtained by us is apparently the symmetrical bis(β-4-nitrophenylvinyl) sulfone (XIX). The latter was reduced with hydrogen in the presence of platinum catalyst, and was isolated as the acetyl derivative (XX).

(XX)
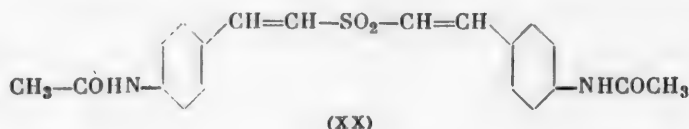
Compound (XX) is the vinylene homolog of bis(p-acetamidophenyl) sulfone, which shows antitubercular activity.

As was to be expected, m-nitro-ω-chlorostyrene, the vinylene homolog of m-nitrochlorobenzene, does not react with sodium sulfide under the conditions that the p-isomer does.

EXPERIMENTAL

The (p-nitrophenyl)(chloromethyl)carbinyl nitrate used had m. p. 82° [2].

The (m-nitrophenyl)(chloromethyl)carbinyl nitrate used had m. p. 84° [2].

(2,4-Dinitrophenyl)(chloromethyl)carbinyl nitrate. Thirty grams of (p-nitrophenyl)(chloromethyl)carbinyl nitrate was added at 40° to a nitrating mixture composed of 12 ml of nitric acid (d 1.5) and 37 ml of sulfuric acid (d 1.84), and then the mixture was carefully heated to 70°. The reaction was exothermic. Cooling was used to keep the temperature below 80°. After holding at this temperature for 30 minutes, the mixture was cooled and poured on ice. The viscous product was washed with water and a little methyl alcohol. Recrystallized from methyl alcohol. Yield 17.6 g (50%). M. p. 105°.

Found %: N 14.21, 14.30. $C_8H_6O_7N_3Cl$. Calculated %: N 14.41.

(3,5-Dinitrophenyl)(chloromethyl)carbinyl nitrate. Obtained in the same manner as the preceding from (m-nitrophenyl)(chloromethyl)carbinol. Yield 34.4%. M. p. 116-117°. The same as the preceding, the compound is insoluble in water and petroleum ether, is soluble in hot alcohol, and is readily soluble in benzene and acetone.

Found %: N 14.16, 14.19. $C_8H_6O_7N_3Cl$. Calculated %: N 14.41.

The (p-nitrophenyl)(chloromethyl)carbinol (I) used had m. p 82° [2].

(m-Nitrophenyl)(chloromethyl)carbinol (VI). A mixture of 8 g of (VI) nitrate [2], 3 g of urea, 11.2 ml of nitric acid (d 1.5) and 42 ml of water was heated under reflux, with stirring, for 4 hours, and then poured into 100 ml of water. The next day the product was filtered. Yield 4.8 g (73.2%). M. p. 44-45°. For analysis, the product was recrystallized from water.

Found %: N 6.65, 6.72. $C_8H_8O_3NCl$. Calculated %: N 6.94.

(2,4-Dinitrophenyl)(chloromethyl)carbinol (XI). Obtained in the same manner as the preceding. Yield 85.2%. M. p. 81-82°.

Found %: N 10.94, 11.06. $C_8H_7O_5N_2Cl$. Calculated %: N 11.35.

(3,5-Dinitrophenyl)(chloromethyl)carbinol (X) was obtained in the same manner as the preceding. Yield 90.8%. M. p. 106-107°.

Found %: N 10.96, 11.09. $C_8H_7O_5N_2Cl$. Calculated %: N 11.35.

Carbinols (VI), (X), and (XI) are difficultly soluble in water and petroleum ether, and readily soluble in alcohol, ether, acetone and benzene. (VI) is readily soluble in carbon tetrachloride, and (X) and (XI) are difficultly soluble.

(2,4-Dinitrophenyl) (chloromethyl) carbinyl acetate. A mixture of 7.5 g of (2,4-dinitrophenyl) (chloromethyl) carbinol and 25 ml of acetic anhydride was refluxed for 2 hours. After cooling, the flask contents were poured into water. The obtained oil was washed with water. The oil gradually crystallized. The crystals were filtered. Recrystallized from methyl alcohol. Yield 6.6 g (75.3%). M. p. 107-108°.

Found %: N 9.72, 9.95. $C_{10}H_9O_6N_2Cl$. Calculated %: N 9.71.

(3,5-Dinitrophenyl) (chloromethyl) carbinyl acetate. Obtained in the same manner as the preceding. Yield 75%. M. p. 111-112°.

Found %: N 9.63, 9.75. $C_{10}H_9O_6N_2Cl$. Calculated %: N 9.71.

2,4-Dinitrostyrene oxide. To a solution of 1 g of (2,4-dinitrophenyl) (chloromethyl) carbinol in 2.5 ml of alcohol was added, at 30-40°, 2.5 ml of 20% aqueous NaOH solution, and the mixture was stirred for 1 hour at 40-50°. After cooling, the compound was filtered, and recrystallized from aqueous alcohol. Yield 0.7 g (82%). M. p. 76°. Readily soluble in ether, acetone, benzene and CCl_4, soluble in hot alcohol, and insoluble in water and petroleum ether.

Found %: N 12.98, 13.08. $C_8H_6O_5N_2$. Calculated %: N 13.33.

Meso-α,α'-di(4-nitrophenyl)-β,β'-dichlorodiethyl ether (V). A mixture of 6 g of (p-nitrophenyl) (chloromethyl) carbinol and 30 g of thionyl chloride was heated at 50° for 1 hour, and then at reflux for 1 hour. The thionyl chloride was distilled off. Recrystallized from alcohol. Yield 4 g (69.5%). M. p. 128-129° [3].

Found %: Cl 18.54, 18.63. $C_{16}H_{14}O_5N_2Cl_2$. Calculated %: Cl 18.44.

Meso-α,α'-di(3-nitrophenyl)-β,β'-dichlorodiethyl ether (VII). Obtained in the same manner as the preceding. The yield, after two recrystallizations from alcohol, was 65%. M. p. 81-82°. The same as the preceding, the compound is insoluble in water, and readily soluble in organic solvents.

Found %: Cl 18.64, 18.68. $C_{16}H_{14}O_5N_2Cl_2$. Calculated %: Cl 18.44.

4-Nitro-1-(α,β-dichloroethyl) benzene (II). To a mixture of 11.5 g of PCl_5 and 25 ml of dry CCl_4 was gradually added 10.08 g of (I), and the mixture refluxed on the water bath for 2 hours. The CCl_4 and $POCl_3$ were distilled in vacuo, using a water-jet pump. The product was recrystallized from aqueous methanol, and then from petroleum ether. Yield 5.85 g (53%). M. p. 55-56°.

Found %: Cl 31.86, 31.98. $C_8H_7O_2NCl_2$. Calculated %: Cl 32.27.

3-Nitro-1-(α,β-dichloroethyl) benzene (VIII) was obtained in the same manner as the preceding. Yield 85%. M. p. 41-42°.

Found %: Cl 31.93, 31.99. $C_8H_7O_2NCl_2$. Calculated %: Cl 32.27.

3,5-Dinitro-1-(α,β-dichloroethyl) benzene (XII). Obtained in the same manner as the preceding. Yield 80%. M. p. 91-92°.

Found %: Cl 26.58, 26.63. $C_8H_6O_4N_2Cl_2$. Calculated %: Cl 26.89.

Compounds (II), (VIII) and (XII) are insoluble in water, soluble in hot petroleum ether, and readily soluble in other solvents.

p-Nitro-α-chlorostyrene (IV). A mixture of 11 g of 4-nitro-1-(α,β-dichloroethyl) benzene, 7.52 ml of triethylamine and 36 ml of alcohol was refluxed on the water bath for 1 hour. The alcohol was distilled off in the vacuum of the water-jet pump. The product was recrystallized from petroleum ether. Yield 8.2 g (83.5%). M. p. 65°.

Found %: N 7.41, 7.48; Cl 19.12, 19.18. $C_8H_6O_2NCl$. Calculated %: N 7.63; Cl 19.35.

3,5-Dinitro-α-chlorostyrene (XIII). Obtained in the same manner as the preceding. Yield 62%. M. p. 56°.

Found %: Cl 15.42, 15.50. $C_8H_5O_4N_2Cl$. Calculated %: Cl 15.49.

m-Nitro-α-chlorostyrene (IX). Obtained in the same manner as the preceding. After distilling off the solvent, the product was dissolved in petroleum ether with heating, and filtered. The petroleum ether was distilled off. The residual oil was vacuum-distilled. B. p. 117-118° at 0.2 mm. Yield 67.5%.

Found %: Cl 19.17, 19.32. $C_8H_6O_2NCl$. Calculated %: Cl 19.35.

The α-chlorostyrenes [compounds (IV), (IX), and (XIII)] are insoluble in water, soluble in hot petroleum ether, and readily soluble in other organic solvents.

p-Nitro-ω-chlorostyrene (III). a) (p-Nitrophenyl)(chloromethyl)carbinol was heated either with anhydrous zinc chloride at 145-150°, or with potassium bisulfate at 200-210°, at a pressure of 10 mm for 15 minutes, after which the product was steam-distilled, and recrystallized from alcohol. Yield 10-15%. M. p. 128°.

b) A thoroughly mixed mixture of 30 g of (p-nitrophenyl)(chloromethyl)carbinol and 30 g of phosphorus pentoxide was heated on the boiling water bath for 2 hours. After cooling, the solidified mass was treated with 50 ml of water. The precipitate was filtered, washed with water, and dried. Recrystallized from methyl alcohol. Yield 12.8 g (46.6%). M. p. 124-125°.

Found %: N 7.86, 7.67. $C_8H_6O_2NCl$. Calculated %: N 7.63.

Some of the product proved to be more difficultly soluble in methyl alcohol, and could be recrystallized from a large volume. This compound is the racemate of α,α'-di(4-nitrophenyl)-β,β'-dichlorodiethyl ether (XIV). Pale yellow prisms. Yield 1 g (3.6%). M. p. 172° [3].

Found %: Cl 18.37, 18.44. $C_{16}H_{14}O_5N_2Cl_2$. Calculated %: Cl 18.44.

m-Nitro-ω-chlorostyrene (XV) was obtained in the same manner as the preceding. Yield 34.6%. M. p. 82-83° [5].

3,5-Dinitro-ω-chlorostyrene (XVI). A mixture of 1 g of (3,5-dinitrophenyl)(chloromethyl)carbinol and 1.2 g of phosphorus pentoxide was heated in an oil bath for 2 hours at 160-180°. The mixture was cooled, water was added, and the whole thoroughly stirred. The product was filtered, washed with water, and dried. Recrystallized from methyl alcohol. Here the first product to deposit was 0.15 g (15.6%) of α,α'-di(3,5-dinitrophenyl)-β,β'-dichlorodiethyl ether (XVII). Pale yellow needles. M. p. 146-147°.

Found %: N 11.45, 11.56. $C_{16}H_{12}O_9N_4Cl_2$. Calculated %: N 11.78.

The mother liquor was evaporated. The obtained 3,5-dinitro-ω-chlorostyrene was recrystallized from methyl alcohol. Yield 0.12 g (13%). M. p. 85-86°. The product is insoluble in water, difficultly soluble in petroleum ether and CCl_4, soluble in hot alcohol, and readily soluble in acetone and benzene.

Found %: N 11.93, 11.99. $C_8H_5O_4N_2Cl$. Calculated %: N 12.25.

Bis(β-4-nitrophenylvinyl)sulfide (XVIII). A solution of 5.15 g of p-nitro-ω-chlorostyrene in 70 ml of methyl alcohol was added to a solution of 3.3 g of crystalline sodium sulfide in 30 ml of methyl alcohol. The mixture was refluxed on the water bath for 2.5 hours. After cooling, the precipitate was filtered, and washed with water, methyl alcohol, and ether. Recrystallized from glacial acetic acid. Yield 3.6 g (78%). M. p. 207-208°. Readily soluble in acetone and in benzene and glacial acetic acid when heated, and insoluble in other solvents.

Found %: S 9.66, 9.72. $C_{16}H_{12}O_4N_2S$. Calculated %: S 9.75.

Bis(β-4-nitrophenylvinyl)sulfone (XIX). Sulfide (XVIII) (2.5 g) was dissolved in 375 ml of hot glacial acetic acid, followed by the addition of 4 ml of 30% hydrogen peroxide, after which the mixture was heated, with stirring, in a boiling water bath for 3.5 hours. The solution gradually changed from an orange to a straw-yellow color. After cooling, the pale yellow crystals were filtered. Yield 2.2 g (80%). M. p. 286-287°. For analysis, the product was recrystallized from glacial acetic acid. Difficultly soluble in hot glacial acetic acid, and insoluble in other solvents.

Found %: N 7.52, 7.70. $C_{16}H_{12}O_6N_2S$. Calculated %: N 7.78.

Bis (β-4-acetamidophenylvinyl) sulfone (XX). A charge of 0.5 g of sulfone (XIX), 0.05 g of platinum oxide and 250 ml of alcohol was placed in a hydrogenation flask and the reduction run with hydrogen for 30 hours at an excess pressure of 100 mm Hg. The platinum black was filtered, and the solution was evaporated to dryness. We obtained 0.4 g of lemon-yellow substance. M. p. 180° (from alcohol). The obtained amine was treated with 2 ml of acetic anhydride. The mixture was heated on the water bath for 1 hour. After cooling, the yellow crystals were filtered, and recrystallized from alcohol. Yield 0.45 g (90.2%). M. p. 292° (decomp.). Soluble in hot acetone and alcohol.

Found %: N 7.33, 7.46; S 7.95, 8.05. $C_{20}H_{20}O_4N_2S$. Calculated %: N 7.29; S 8.33.

SUMMARY

(3,5-Dinitrophenyl) (chloromethyl) carbinol, (2,4-dinitrophenyl) (chloromethyl) carbinol, and their nitrates and acetates, were synthesized. It was shown that α,α'-di (nitrophenyl)-β,β'-dichlorodiethyl ethers are formed when (nitrophenyl) (chloromethyl) carbinols are reacted with thionyl chloride, and α,β-dichloro-substituted ethylnitrobenzenes when reaction is with phosphorus pentachloride. The latter compounds cleave hydrogen chloride to yield nitro-substituted α-chlorostyrenes.

A convenient method was found for the preparation of nitro derivatives of ω-chlorostyrenes by the cleavage of water from the corresponding carbinols. It was shown that, in contrast to the m-isomer, p-nitro-ω-chlorostyrene possesses a labile halogen. The vinylene homolog of bis (4-acetamidophenyl) sulfone was obtained.

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THE PROBLEM OF THE RECIPROCAL TRANSFORMATION OF
CIS-TRANS ISOMERS

II. AZOBENZENE

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A recent review of data for the polarographic behavior of organic compounds [1] gives the half-wave potentials at the saturated calomel electrode of cis-azobenzene in alcohol (supporting electrolyte LiCl) as 1.63 and in 75% dioxane [supporting electrolyte $(C_2H_5)_4NI$] as 0.80; for trans-azobenzene, under the same conditions as the latter, the value is given as 0.97 v. According to Hillson and Birnbaum [2] the two stereoisomeric azobenzenes in an acid medium are reduced at the same potential while in a caustic alkaline medium they are reduced at different potentials. Their study of the reduction of azobenzene in an acetate buffer led these authors to believe that the reduction is irreversible. Castor and Saylor [3] carried out the process in a citrate — phosphate buffer solution and concluded that the reduction is reversible; according to their data two electrons participate in the process. Foffani and Fragiocomo [4] regarded the shape of the polarographic curve during reduction of azobenzene as evidence that one electron participates in the process. In a review paper [5] Wawzonec sums up the position by saying that the conflicting data for the behavior of azobenzene at the dropping mercury cathode prevent us at present from reaching a definite conclusion as to whether this electrode process is reversible or irreversible.

This uncertainty prompted us to re-examine the behavior of azobenzene at the dropping mercury cathode.

We synthesized hydrazobenzene and oxidized it to azobenzene with sodium nitrite in ether solution [6]. The product was twice recrystallized from alcohol. M. p. 68° in good agreement with the literature.

We investigated azobenzene in McIlheny buffer mixtures with 1 N potassium chloride solution but in each case with a 25% content of alcohol in the medium since azobenzene is insoluble in water. The capillary had the characteristic of $m^{2/3} \cdot t^{1/6} = 1.15 \text{ mg}^{2/3} \cdot \text{sec}^{-1/2}$ where $m = 0.885$ mg/sec and $t = 3.75$ sec.

Influence of the pH of the medium. The behavior of azobenzene in buffer solutions was examined in the pH range of 0.02 to 12.39. At pH values up to 1.94, azobenzene gives no polarographic wave; at higher values, contrary to the findings of Hillson and Birnbaum, it gives two waves with a difference between the half-wave potentials of 0.2 to 0.3 v (Table 1). Both of the waves are rectilinearly shifted toward more negative values of $E_{1/2}$ with increasing alkalinity of the medium. The first wave is about three times as high as the second wave. With increasing pH of the medium the height of the first wave increases slightly; on the other hand the diffusion current of the second wave very slightly decreases with increasing alkalinity of the medium.

All of the data of Table 1 are related to a $1 \cdot 10^{-3}$ M concentration of azobenzene.

Influence of the alcohol content of the medium. Azobenzene was studied polarographically in 25, 50, 75, and 100% alcoholic solutions of 0.1 N ammonium chloride. The azobenzene concentration was $1 \cdot 10^{-3}$ M (Table 2). Two prominent waves are obtained in all of the media with a half-wave potential difference between them of 0.3-0.4 v. With increasing alcohol content of the medium the two half-wave potentials are shifted in the negative direction. The ratio between the heights of the waves is the same as during polarography in buffer

media (i.e., the first wave is about three times as high as the second wave). The diffusion current of both of the waves increases very slightly with increasing alcohol content of the medium.

TABLE 1

Influence of the pH of the Medium on the Polarographic Behavior of Azobenzene

pH	First wave		Second wave	
	$E_{1/2}$ (v)	i_d (μa)	$E_{1/2}$ (v)	i_d (μa)
0.02	—	—	—	—
1.94	—	—	—0.37	0.959
2.93	—0.24	2.329	—0.49	0 822
4.49	—0.42	2.603	—0.68	0˙822
5.20	—0.42	2.740	—0.69	1˙096
6.22	—0.45	2.466	—0.71	0˙959
7.00	—0.53	2.740	—0.80	1˙096
7.88	—0.57	2.466	—0.86	0.822
8.75	—0.69	2.877	—0.96	1.096
9.42	—0.73	2.603	—0.98	0.959
11.21	—0.77	2.740	—0.99	0.822
12.39	—0.81	2.740	—1.03	0.685
Mean	—	2.630	—	0.918

TABLE 2

Influence of Alcohol Content of Solution on the Polarographic Behavior of Azobenzene

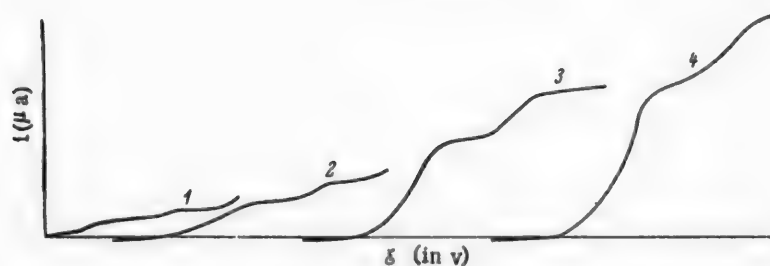| Alcohol concentration (in %)	First wave		Second wave	
	$E_{1/2}$ (v)	i_d (μa)	$E_{1/2}$ (v)	i_d (μa)
25	—0.46	2.740	—0.76	0.959
50	—0.54	3.014	—0.87	0.959
75	—0.51	3.425	—0.90	1.233
100	—0.57	3.836	—0.96	1.507

Fig. 1. Polarogram of alcoholic solution of azobenzene ($\eta = 1/25$). Concentrations (molar): 1) $0.5 \cdot 10^{-3}$, 2) $1 \cdot 10^{-3}$, 3) $3 \cdot 10^{-3}$, 4) $5 \cdot 10^{-3}$.

The relation between diffusion current and azobenzene concentration was examined for all four alcoholic solutions. Results are presented in Table 3. The two half-wave potentials remain unchanged in the same medium and do not vary with the azobenzene concentration. Direct proportionality between diffusion current and azobenzene concentration is maintained in all of the aqueous alcoholic solutions. As an example (Fig. 1) we show one of a series of polarograms plotted for a purely alcoholic solution.

TABLE 3

Relation Between Diffusion Current and Azobenzene Concentration

Azobenzene concentration (in milli-moles)	Proportionality coefficient $\frac{i_d}{C}\left(\frac{\mu a}{mmoles}\right)$							
	25% alcohol		50% alcohol		75% alcohol		100% alcohol	
	first wave	second wave	first wave	second wave	first wave	second wave	first wave	second wave
0.5	2.730	1.002	3.126	1.020	3.512	1.208	3.852	1.572
1.0	2.740	0.959	3.014	0.959	3.425	1.233	3.836	1.507
3.0	2.747	0.965	3.013	0.967	3.428	1.237	3.840	1.512
5.0	2.723	1.003	3.129	1.020	3.516	1.225	3.861	1.569
Mean	2.735	0.982	3.070	0.991	3.470	1.226	3.847	1.540

The slopes of the $E_{1/2}$ versus pH curves of the first and second waves of azobenzene (Fig. 2) show that the half-wave potentials are shifted by about 0.06 v per pH unit, corresponding to reduction with participation of two electrons. This conclusion was tested by construction of a graph of $\log \frac{i}{i_d - i}$ versus E for a citrate—phosphate buffer with pH of 5.2 and an azobenzene concentration of $1 \cdot 10^{-3}$ M (Fig. 3). The tangents of the angle of slope of the resulting straight-line plots gave values of 1.9 and 0.84 for the first and second wave, respectively. Judging by the first wave (which is more prominent, has a greater height and therefore provides more accurate values) the process of reduction of azobenzene at the dropping mercury cathode is reversible and goes with consumption of two electrons: the angular coefficient is found to be 0.031, as compared with a value of 0.03 for a two-electron process.
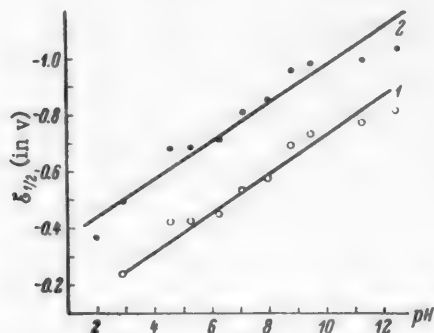
Fig. 2. Relation between $E_{1/2}$ and the pH. 1) First wave; 2) second wave.
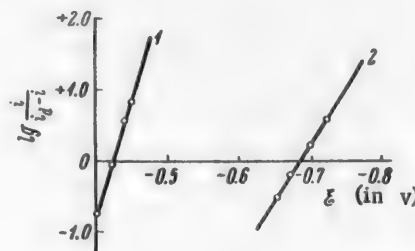
Fig. 3. Plots of $\log \frac{i}{i_d - i}$ versus E. 1) First wave; 2) second wave.

The half-wave potentials obtained experimentally in this medium are in good agreement with the plotted values: the $E_{1/2}$ found for the first wave is -0.42 v and the graphical value is -0.425 v ; the experimental value of $E_{1/2}$ of the second wave is -0.69 and the graphical value is -0.685.

The existence of two waves in definite and constant ratios at various pH values and in different aqueous alcoholic media leads one to think that these two waves originate from the two modifications of azobenzene — the cis and trans-forms. This hypothesis is supported by the results obtained by Winkel and Siebert [7] when they irradiated azobenzene with ultraviolet light. This treatment led to decline, and ultimately to disappearance, of one of the waves while the second one increased. Our own experiments confirm this behavior.

TABLE 4

Influence of the pH of the Medium on the Polarographic Behavior
of Irradiated Azobenzene

pH	First wave		Second wave	
	$E_{1/2}$ (v)	i_d (μa)	$E_{1/2}$ (v)	i_d (μa)
0	—	—	—	—
1.94	—	—	—0.37	0.722
2.93	—0.25	2.877	—0.47	0.710
4.49	—0.40	2.808	—0.65	0.768
5.20	—0.42	2.788	—0.68	0.760
6.22	—0.45	2.760	—0.71	0.722
7.00	—0.52	2.986	—0.78	0.760
7.88	—0.58	3.002	—0.85	0.710
8.75	—0.67	2.986	—0.93	0.768
9.42	—0.72	2.808	—0.98	0.742
11.21	—0.78	2.877	—0.99	0.720
12.39	—0.83	3.002	—1.05	0.608
Mean	—	2.889	—	0.727

Solutions of azobenzene in buffered 25% aqueous alcoholic media with a concentration of $1 \cdot 10^{-3}$ molar were irradiated with sunlight in a quartz vessel for three days. They were then polarographed. In another set of experiments solutions of azobenzene in 0.1 N ammonium chloride with various alcohol contents were irradiated. Results of polarographic measurements are presented in Tables 4 and 5.

TABLE 5

Influence of Content of Alcohol in
Solution on the Polarographic Behavior
of Irradiated Azobenzene

Alcohol concentration (in %)	First wave		Second wave	
	$E_{1/2}$ (v)	i_d (μa)	$E_{1/2}$ (v)	i_d (μa)
25	—0.45	2.946	—0.75	0.742
50	—0.52	3.320	—0.85	0.806
75	—0.52	3.842	—0.88	0.938
100	—0.58	4.228	—0.95	0.086

TABLE 6

Transition of cis-Form to trans-Form

Duration of standing (hr)	cis-Form		trans-Form		$K \cdot 10^3$
	i_d (μa)	$C \cdot 10^3$	i_d (μa)	$C \cdot 10^3$	
96	30.82	4.85	—	—	—
120	29.45	4.64	3.42	0.62	1.90
144	25.34	3.99	4.79	4.79	4.08
168	24.66	3.88	6.16	6.16	3.10
Mean			—		3.03

It is noteworthy that in all of the media the wave heights are in the ratio of 4:1 and not of 3:1 as in the case of nonirradiated azobenzene. After the irradiated solutions had stood in the dark for two months, their polarographic curves were identical with the curves of the substance prior to irradiation.

If we designate the content of cis-form in ordinary azobenzene by x and that in irradiated azobenzene by x + y, then we can write

$$2.889\ x = 2.630\ (x+y),$$
$$0.727\ (100-x) = 0.918\ (100-x-y),$$

Hence, $x = 67.7$ and $y = 6.7$. This signifies that ordinary azobenzene contains 67.7% cis-form and 32.3% trans-form, while after irradiation under our conditions the content of cis-azobenzene rose by 10%.

A second irradiation experiment was carried out with $1 \cdot 10^{-2}$ molar solution of azobenzene in pure alcohol. After 3 hours' irradiation with ultraviolet light, the second wave (corresponding to the trans-form) had completely disappeared. After standing in the dark for four days the irradiated specimen had not undergone any change in polarographic behavior. On the fifth day, the wave of the cis-form began to decrease and the wave of the trans-form again appeared. At the end of the eighth day the ratio of wave heights existing before irradiation had been restored (Table 6).

We calculated the diffusion coefficient of azobenzene on the basis of the first wave. For a total azobenzene concentration of 1 mmole/liter we assumed that the concentration of cis-form was 67.7% of 1 mmole; $z = 2$, $i_d = 2.740$ when $m^{2/3} \cdot t^{1/6} = 1.15$ mg$^{2/3} \cdot$ sec$^{-1/2}$ in a buffered citrate-phosphate medium with pH of 5.2. Hence, we obtain a value of $D = 7.84 \cdot 10^{-6}$ cm$^2 \cdot$ sec^{-1}. According to [8], the coefficient of diffusion of azobenzene in 96% alcohol is $7.4 \cdot 10^{-6}$ cm$^2 \cdot$ sec^{-1}. This good agreement confirms firstly the validity of our hypothesis about reduction of azobenzene with participation of two electrons, and secondly the validity of the conclusion that ordinary azobenzene contains 67.7% of cis-form and that the first wave is associated with the cis-form.

The two forms of azobenzene are reduced to hydrazobenzene

$$C_6H_5N=NC_6H_5 + 2e + 2H \cdot \rightleftarrows C_6H_5NH-NHC_6H_5,$$

and the difference between the half-wave potentials of the cis- and trans-forms during reduction is due to the higher energy content of the cis-form. We can calculate the energy of transition of one form into the other by the Gibbs—Helmholtz equation:

$$E - T\frac{dE}{dT} = \frac{Q_p}{23060z},$$

where E is the mean difference between the half-wave potentials of the first and second waves of azobenzene (in our case 0.27 v); Q_p is the thermal effect or energy of transition; z is the number of electrons participating in the reaction (in our case $z = 2$). In this manner, we obtain a value of $Q_p = 12.45$ kcal/mole.

On the basis of the effect of the light absorption of the two forms of azobenzene and the difference in their heats of melting, Hartley [9] found an energy of conversion of cis- into trans-azobenzene of approximately 12 kcal/mole. This is in good agreement with our value.

SUMMARY

The polarographic behavior of azobenzene was studied. It was found to comprise 67.7% cis-form and 32.3% trans-form. Irradiation converts the trans- to the cis-form; after a certain induction period in the dark, the cis-form then undergoes a spontaneous reversible transition. Reduction of both of the forms at the cathode proceeds reversibly with participation of two electrons. The diffusion coefficient of azobenzene was calculated; the energy of transition of the cis- to the trans-form was calculated on the basis of the difference between the half-wave potentials.

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THE REACTION OF ETHYL DIAZOACETATE WITH 9-PHENYL- AND WITH 9-(p-TOLYL)-9-BROMOFLUORENES. SYNTHESIS OF FLUORENE AND PHENANTHRENE DERIVATIVES
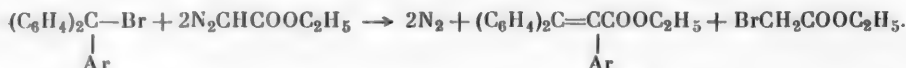
I. A. D'yakonov and T. V. Domareva
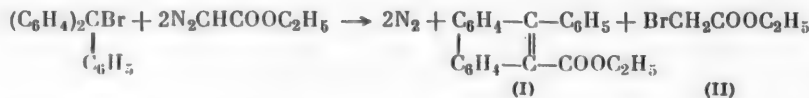
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It was recently reported that reaction of ethyl diazoacetate with 9-bromofluorene in presence of copper sulfate [1] gives only 9,9'-difluoryl and bromoacetic ester instead of the expected product of condensation of the two reactants — the ethyl ester of 9-fluorylbromoacetic acid $(C_6H_4)_2CHCHBrCOOC_2H_5$.

This result can be explained by the low stability of the free fluoryl radical formed in course of the chain reaction with ethyl diazoacetate [1]. Since the introduction of an aryl group into the 9 position is bound to increase the stability of the radical, it was to be expected that the reaction with 9-aryl-9-bromofluorenes would go more successfully than the reaction with unsubstituted 9-bromofluorene. The present work was undertaken for the purpose of subjecting this hypothesis to experimental check. Here we present the results of reaction between ethyl diazoacetate and 9-phenyl- and 9-(p-tolyl)-9-bromofluorene.

Both of these bromo compounds are similar in composition and structure to triphenylbromomethane. The behavior of the latter toward ethyl diazoacetate has already been studied [2]. It was therefore to be expected that both of the compounds would react in similar fashion to triphenylbromomethane, i.e., with cleavage of HBr and migration of the aryl group with formation of condensation product:

$$(C_6H_4)_2\underset{Ar}{C}{-}Br + 2N_2CHCOOC_2H_5 \longrightarrow 2N_2 + (C_6H_4)_2\underset{Ar}{C}{=}CCOOC_2H_5 + BrCH_2COOC_2H_5.$$
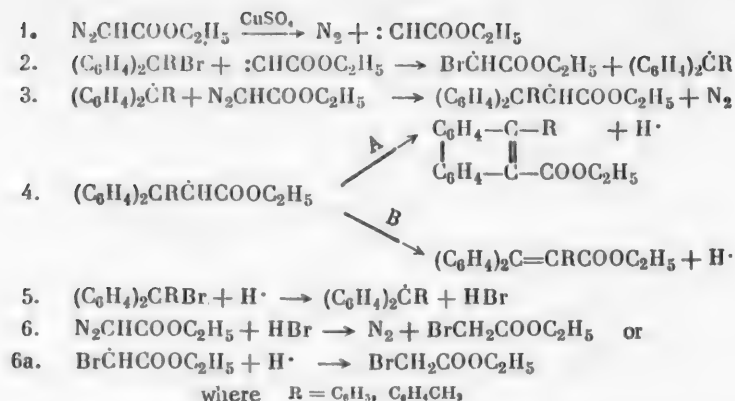
The reaction with 9-phenyl-9-bromofluorene gave a product with the expected composition, but its structure was different. Further investigation showed that rearrangement takes place during the reaction with expansion of the five-membered ring to a six-membered ring and with formation of a phenanthrene derivative:

$$(C_6H_4)_2\underset{C_6H_5}{C}Br + 2N_2CHCOOC_2H_5 \longrightarrow 2N_2 + \underset{\underset{(I)}{C_6H_4{-}\overset{\|}{C}{-}COOC_2H_5}}{C_6H_4{-}C{-}C_6H_5} + \underset{(II)}{BrCH_2COOC_2H_5}$$

Reaction of 1.5 moles ethyl diazoacetate per mole bromo compound gave yields of esters (II) and (I) of 16.2 and 18.6% of the theoretical (calculated on the ethyl diazoacetate).

The same rearrangement with ring expansion was also observed in the case of 9-bromo-(p-tolyl)-fluorene; it was accompanied, however, by a reaction similar to that described for triphenylbromomethane and leading to synthesis of ester (IV).

$$2N_2 + \begin{array}{c} C_6H_4-C-C_6H_4CH_3 \\ \parallel \\ C_6H_4-C-COOC_2H_5 \end{array} + BrCH_2COOC_2H_5$$

$$(\text{III})$$

$$(C_6H_4)_2CBr + 2N_2CHCOOC_2H_5$$
$$\begin{array}{c} | \\ C_6H_4CH_3 \end{array}$$

$$2N_2 + \begin{array}{c} C_6H_4 \\ | \\ C_6H_4 \end{array} \!\!\! > \!\! C = CCOOC_2H_5$$
$$\begin{array}{c} | \\ C_6H_4CH_3 + BrCH_2COOC_2H_5 \end{array}$$

$$(\text{IV})$$

When the amount of ethyl diazoacetate brought into reaction was 10% greater than the theoretical requirement, the yield of ester (III) was 29.4% of the theoretical, calculated on the original ethyl diazoacetate. Ester (IV) was not isolated in the pure state, but hydrolysis of the crude reaction product gave the acid (IV A) corresponding to ester (IV); yield 22.1%.

The amount of 9-aryl-9-bromofluorene entering into reaction was also determined in both of the experiments. This was done by heating the reaction mixture with alcoholic caustic alkali. The quantity of 9-aryl-9-ethoxyfluorene formed was a measure of the quantity of bromo derivative that had not reacted with ethyl diazoacetate.

The ethyl esters of 9-arylphenanthrene-10-carboxylic acids (I) and (III) and α-(p-tolyl)-β,β-diphenyleneacrylic acid (IVA) are here described for the first time. The structure of the first two compounds was verified by their conversion to the corresponding acids (IA and IIIA). Acid (IA) was found to have been mentioned in [3]. Its identity with our product was demonstrated by comparison of the melting points and by some special reactions of the two acids. The structure of the acid was finally confirmed by its conversion by the literature method into 1,2,3,4-dibenzofluorenone (V) [3]. A similar reaction was performed with the homologous acid (IIIA) which has not been described in the literature.

$$\begin{array}{c} C_6H_4-C-C_6H_4X \\ \parallel \\ C_6H_4-C-COOH \end{array} + SOCl_2 \rightarrow \begin{array}{c} C_6H_4-C \\ \parallel \\ C_6H_4-C \\ | \\ C \\ \parallel \\ O \end{array} \!\!\! X + SO_2 + 2HCl$$

(I A) X = H; (III A) X = CH   (V) X = H; (VI) X = CH₃

1,2,3,4-Dibenzo-7-methylfluorenone (VI) was previously unknown.

Proof of the structure of acid (IVA) was obtained by oxidizing it with $KMnO_4$ solution. It gave, as expected, fluorenone and p-tolylformic acid; the latter was identified as its phenylhydrazone.

$$\begin{array}{c} C_6H_4 \\ | \\ C_6H_4 \end{array} \!\!\! > \!\! C = C - COOH \xrightarrow{KMnO_4} \begin{array}{c} C_6H_4 \\ | \\ C_6H_4 \end{array} \!\!\! > \!\! C = O + O = C - COOH$$
$$\begin{array}{c} | \\ C_6H_4CH_3 \end{array} \qquad\qquad\qquad \begin{array}{c} | \\ C_6H_4CH_3 \end{array}$$

(IV A)

We had previously put forward the theory of a free-radical chain mechanism of the copper-catalyzed reactions of ethyl diazoacetate with halohydrocarbons [1]. According to this theory, the reactions of ethyl diazoacetate with 9-phenyl- and 9-(p-tolyl)-9-bromofluorenes can be represented by the following scheme:

1. $N_2CHCOOC_2H_5 \xrightarrow{CuSO_4} N_2 + :CHCOOC_2H_5$

2. $(C_6H_4)_2CRBr + :CHCOOC_2H_5 \longrightarrow Br\dot{C}HCOOC_2H_5 + (C_6H_4)_2\dot{C}R$

3. $(C_6H_4)_2\dot{C}R + N_2CHCOOC_2H_5 \longrightarrow (C_6H_4)_2CR\dot{C}HCOOC_2H_5 + N_2$

4. $(C_6H_4)_2CR\dot{C}HCOOC_2H_5$

$A \nearrow$
$$\begin{array}{c} C_6H_4-C-R \\ | \parallel \\ C_6H_4-C-COOC_2H_5 \end{array} + H\cdot$$

$B \searrow$
$$(C_6H_4)_2C{=}CRCOOC_2H_5 + H\cdot$$

5. $(C_6H_4)_2CRBr + H\cdot \longrightarrow (C_6H_4)_2\dot{C}R + HBr$

6. $N_2CHCOOC_2H_5 + HBr \longrightarrow N_2 + BrCH_2COOC_2H_5$ or

6a. $Br\dot{C}HCOOC_2H_5 + H\cdot \longrightarrow BrCH_2COOC_2H_5$

where $R = C_6H_5,\ C_6H_4CH_3$

Stabilization of the radical at step 4 is accompanied by migration of one of the aryl groups. Migration of the phenylene group leads to expansion of the five-membered fluorene ring to a six-membered ring. The mode of stabilization of the radical (4A or 4B) will evidently depend on the relative lability of the aromatic groups. In the present case, as shown by the yields of the respective reaction products, the mobilities of the aromatic groups can be arranged in the order phenyl < tolyl $\simeq$ phenylene. A similar observation regarding the relative mobility of aromatic groups was previously made with reference to the pinacolin rearrangement of the corresponding pinacones of the aromatic series [4, 5].

Expansion of a five-membered to a six-membered ring in course of free-radical stabilization (4A) indicates that the migrating group links up at a new position in the molecule through the same carbon atom with which it had previously been linked with the molecule. This is proved by the formation of the ester of α-(p-tolyl)-β,β-diphenyleneacrylic acid (Equation 4B, $R = C_6H_4CH_3$) in the reaction of ethyl diazoacetate with 9-(p-tolyl)-9-bromofluorene.

EXPERIMENTAL

I. Condensation of Ethyl Diazoacetate with 9-Phenyl-9-bromofluorene

1. Ethyl ester of 9-phenylphenanthrene-10-carboxylic acid (I). 45 g 9-phenyl-9-bromofluorene with m. p. 97-99° [6], 0.2 g anhydrous copper sulfate and 30 ml cyclohexane were heated on a water bath until the whole of the 9-phenyl-9-bromofluorene had dissolved. Thereupon, without interruption of heating, 25 g ethyl diazoacetate, which had been steam-distilled in vacuo [7], was added dropwise with mechanical stirring. Nitrogen was evolved during the reaction and ceased to come off when the whole of the diazo ester had been added. The duration of the experiment was 3 hours. After completion of the reaction, the hot mixture was filtered from catalyst and left to crystallize. Crystals of ester (I) were deposited on cooling. The mother liquor (A) was examined separately (see below). Crude product (I) was purified by crystallization from acetone. There was obtained 4.8 g (16% calculated on the original ethyl diazoacetate) of analytically pure product with m. p. 128-129°.

Found %: C 84.39; H 5.72; OC_2H_5 13.75. $C_{20}H_{13}COOC_2H_5$. Calculated %: C 84.63; H 5.55; OC_2H_5 13.80.

2. Investigation of the mother liquor (A). The liquor (A) was distilled for removal of solvent (cyclohexane). The cooled residue deposited crystals which were then filtered from mother liquor (B) and recrystallized from benzene (for examination of mother liquor B, see 3). M. p. 94-104°, weight 3.7 g. Further investigation showed that the crystals were a mixture of 9-phenyl-9-ethoxyfluorene and ester (I). The components were separated by heating of the crystals for 10 hours with a solution of 30 g potassium hydroxide in 130 ml 80% alcohol. The alcohol was thereupon distilled with steam. The residual alkaline solution deposited a small quantity of solid substance. This was brought into solution in ether and the solution was dried with calcium chloride, the ether was distilled off, and the residue recrystallized from alcohol to give 1.2 g 9-phenyl-9-ethoxyfluorene with m. p. 113-115°. A mixture with an authentic specimen (m. p. 113°), obtained by heating 9-phenyl-9-bromofluorene with alcohol [8], did not give a depression of melting point.

The residual alkaline solution, from which the 9-phenyl-9-ethoxyfluorene had been extracted, was cooled with ice and carefully acidified with dilute sulfuric acid. An oily acid separated out and was dissolved in ether. The ethereal extract was dried with anhydrous sodium sulfate and part of the solvent was taken off on a water bath. The concentrated ethereal solution was cooled and deposited a solid acid which was then filtered and crystallized from a mixture of alcohol and benzene (1:1). It weighed 1.8 g and melted at 188-189°. The acid did not give a depression of melting point in admixture with 9-phenylphenanthrene-10-carboxylic acid prepared by alkaline hydrolysis of the corresponding ethyl ester (see 4 below). According to [3], acid 1A melts at 185 to 187°. It follows that the crystals with m. p. 94-104° are indeed a mixture of 9-phenyl-9-ethoxyfluorene with ester (I). Taking into account the quantity of ester (I) previously isolated (4.8 g, see 1) and the quantity of ester corresponding to the prepared acid IA, we must assume that the total yield of ester (I) in the reaction with ethyl diazoacetate must be not less than 6.65 g (18.5%).

3. Investigation of mother liquor B. The mother liquor was fractionally distilled in a vacuum of 160 mm to give three fractions: 1st, b. p. 35-40°, 7.7 g — cyclohexane; 2nd, b. p. 40-108°, 0.9 g — an intermediate fraction; and 3rd, b. p. 108-110°, 3.4 g — ethyl bromoacetate (II). The undistillable residue of dark resin weighed 28.3 g.

After distillation at normal pressure, ester (II) had b. p. 159-169° and $n^{20}D$ 1.453. Literature data for ester (II): b. p. 159° at 760 mm, $n^{20}D$ 1.454 [9]. Final proof of the identity of ester (II) was obtained by its conversion by the literature method [10] into bromoacetamide which melted at 91° [10] and did not give a depression of melting point in admixture with an authentic specimen.

The undistillable residue (28.3 g) obtained by fractional distillation of mother liquor B was subjected to heating for 7 hours with 250 ml 10% potassium hydroxide solution in alcohol. The objective of this operation was to establish whether the residue contained any ester (I) and unreacted 9-phenyl-9-bromofluorene. After completion of heating, the alcohol was driven off with steam and the residue in the flask was diluted with water. Not all of the residue went into solution. The insoluble portion was extracted with ether, while the aqueous solution was acidified with dilute sulfuric acid. The resulting dark-colored acid was a viscous resin which could not be purified by crystallization from organic solvents. It was not further examined.

The ethereal extract of the product insoluble in alkali solution was dried with calcium chloride and the ether was driven off. The crystals that separated from the concentrated ethereal solution were twice recrystallized from alcohol. They then melted at 112-113° and weighed 6 g. A mixture with authentic 9-phenyl-9-ethoxy-fluorene (m. p. 112-114°, compare 2) did not exhibit a depression of melting point. The total yield of ethoxy derivative, taking into account the previously isolated substance (1.2 g, see 2) was 7.2 g. We can thus calculate the quantity of 9-phenyl-9-bromofluorene that did not enter into reaction with ethyl diazoacetate. It was 8.1 g or 20% of the original 9-phenyl-9-bromofluorene.

4. 9-Phenylphenanthrene-10-carboxylic acid (IA). 4.8 g ester (I) with m. p. 128-129° (see 1) and 125 ml 10% potassium hydroxide solution were refluxed for 8 hours. The alcohol was distilled off with steam, the residue was diluted with water, and the alkaline solution was acidified with dilute sulfuric acid. Crude acid (IA) separated in the quantity of 4.3 g (94.3%), m. p. 182-185°. After crystallization from a mixture of chloroform and acetone it melted at 187-189° (literature [3]: m. p. 185-187°). The acid forms fine, colorless crystals poorly soluble in alcohol; it is not oxidized by permanganate in an alkaline medium; it gives a red-violet color with concentrated sulfuric acid. The isomeric α-phenyl-β,β-diphenyleneacrylic acid (m. p. 182-183° [11]), which could be obtained by alkaline hydrolysis of the corresponding ester (see equation in the introductory part of this paper), gives a green color with concentrated sulfuric acid [11].

Taking into account the previously isolated quantity (1.8 g, see 2), the total yield of IA is 6.1 g.

Found %: C 84.53; H 5.02; OH 5.46. $C_{21}H_{14}O_2$. Calculated %: C 84.54; H 4.73; OH 5.70.

Final proof of the identity of acid (IA) was obtained by its conversion by Kölsch's method [3] into the known 1,2,3,4-dibenzofluorenone (V) [3, 12].

From 1 g (IA) was obtained 0.72 g (V) with m. p. 183-184° (73.8%). After recrystallization from glacial acetic acid, (V) had m. p. 185-186° in agreement with the literature.

Found %: C 89.74; H 4.65. $C_{21}H_{12}O$. Calculated %: C 89.98; H 4.31.

II. Condensation of Ethyl Diazoacetate with 9-(p-Tolyl)-9-bromofluorene

1. Synthesis of the starting 9-(p-tolyl)-9-bromofluorene.* 40 ml acetyl bromide was added slowly to a hot solution of 44 g 9-(p-tolyl)-9-fluorenol in 50 ml dry benzene. After completion of the addition, the mixture was heated one hour on a water bath. The benzene and unreacted acetyl bromide were then distilled off at atmospheric pressure. The residue in the distillation flask crystallized on cooling. The crystals were separated from the mother liquor and twice recrystallized from ligroine to give 36.3 g (68%) of 9-(p-tolyl)-9-bromofluorene with m. p. 122-123°.

Found %: Br 23.68. $C_{20}H_{15}Br$. Calculated %: Br 23.84.

The product is in the form of stout prisms, readily soluble in benzene and chloroform, less soluble in ether, slightly soluble in cold ligroine. Darkens during recrystallization from high-boiling solvents.

For confirmation of its structure, the bromo compound was converted into 9-(p-tolyl)-9-ethoxyfluorene which has been described in [13]. For this purpose, 3 g 9-(p-tolyl)-9-bromofluorene and 15 ml alcohol were heated 15 minutes on a boiling water bath. On cooling, the solution deposited crystals of 9-(p-tolyl)-9-ethoxyfluorene. These were filtered off, washed with a little alcohol and dried. Yield 2.42 g (89.2%). M. p. 123-124°; the literature [13] gives m. p. 123°.

2. Ethyl ester of 9-(p-tolyl)-phenanthrene-10-carboxylic acid (III). Reaction was effected between 33.5 g 9-(p-tolyl)-9-bromofluorene and 13 g ethyl diazoacetate in presence of 0.1 g anhydrous copper sulfate and 20 ml cyclohexane. The experiment was run under the same conditions as for 9-phenyl-9-bromofluorene (I, 1). Catalyst was removed by filtration and the mass was cooled to room temperature. Crystals of ester (III) came down. They were filtered from mother liquor (see 3 below), washed with a little ether and dried in vacuo. Two crystallizations from a mixture of alcohol and benzene (1:1) gave ester (III) with a constant m. p. of 154-155°. Yield 5.5 g (29.4%).

Found %: C 84.58; H 5.90; OC_2H_5 13.09. $C_{21}H_{15}COOC_2H_5$. Calculated %: OC_2H_5 13.22; C 84.66; H 5.92.

3. Investigation of the mother liquor. α-(p-Tolyl)-β,β-diphenyleneacrylic acid (IVA). The mother liquor separated from the crystals of (III) was a lachrymator; the presence of ethyl bromoacetate was therefore assumed. The liquor was distilled at first at atmospheric pressure and then in vacuo for removal of cyclohexane and ethyl bromoacetate. The ester was not isolated pure because its formation had been demonstrated in an analogous experiment involving 9-phenyl-9-bromofluorene (see I, 3).

The resinous residue (33 g) from the distillation of the mother liquor was heated 8 hours with 125 ml 10% alcoholic potassium hydroxide. The purpose of this operation was the preparation of 9-(p-tolyl)-phenanthrene-10-carboxylic acid, which could have been formed by alkaline hydrolysis of its ester (III); another objective was the isolation of 9-(p-tolyl)-9-ethoxyfluorene — the product of interaction of 9-(p-tolyl)-9-bromofluorene with alcohol. It was assumed in this connection that the resinous residue contained mainly ester (III) and original bromo derivative. After completion of the heating with alkali, the alcohol was driven off with steam and the flask residue was diluted with water. Some of the residue went into solution. The insoluble part was extracted with ether, the ether extract was dried with anhydrous sodium sulfate, and the ether was driven off on a water bath. The residue consisted of crystals of crude 9-(p-tolyl)-9-ethoxyfluorene which were recrystallized first from alcohol and then from benzene. M. p. 121-123°; the literature [13] gives 121-123°. A mixture with an authentic specimen did not suffer a depression of melting point. Weight 6.2 g, corresponding to 6.9 g original 9-(p-tolyl)-9-bromofluorene. The quantity of 9-(p-tolyl)-9-bromofluorene entering into reaction could there - fore be calculated. It was equal to 26.6 g (77% of the total taken).

The aqueous alkaline layer, remaining after separation of the ether extract of 9-(p-tolyl)-9-ethoxyfluorene, was cooled in iced water and carefully acidified with dilute sulfuric acid (to Congo). The acid (IVA) that separated was filtered off and dried. Yield 5.7 g, m. p. 189-194°. Crystallization from acetic acid and then from a mixture of chloroform and carbon tetrachloride gave 3.8 g of (IVA) (22.1% calculated on the ethyl diazoacetate). M. p. 204-206°. The acid is in the form of lemon-yellow prisms, readily soluble in alcohol, ether and chloroform.

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* This is the first time the bromo compound has been prepared. The literature describes only the preparation of the corresponding chloro derivative by a method different from that here given [13].

Found %: C 84.41; H 5.48. Equiv. 311.0. $C_{22}H_{16}O_2$. Calculated %: C 84.56; H 5.16. Equiv. 312.3.

4. Oxidation of acid (IVA). The calculated quantity of potassium permanganate (1.4 g) was gradually added with external cooling to a solution of 1.8 g sodium salt of acid (IVA) and 3 g sodium carbonate in 75 ml water. After the violet color had disappeared, the aqueous solution of oxidation products was filtered from manganese dioxide and from the fluorenone resulting from oxidation. The precipitate was well washed on the filter with water; the wash liquors were added to the filtrate. The fluorenone was then separated from the manganese dioxide by treatment with ether. The ethereal extract yielded 0.6 g (60%) of fluorenone with m. p. 81-83°; the literature [14] reports m. p. 83°. A mixture with authentic fluorenone did not give a depression.

The aqueous solution of oxidation products was cooled to 0°, acidified with dilute sulfuric acid and extracted with ether in a perforator. From the ethereal extract was obtained 0.5 g oil together with a minute amount of crystals. The oil was crude p-tolylformic acid,* which was identified in the form of its phenylhydrazone. The yield of the phenylhydrazone was 0.3 g (21.7%) calculated on the original acid (IVA). M. p. 141-143° (from gasoline − benzene mixture); the literature [15] gives m. p. 143°. No depression of melting point in a mixed test with the phenylhydrazone prepared from authentic p-tolylformic acid.

6. 9-(p-Tolyl)-phenanthrene-10-carboxylic acid (IIIA). 1 g of (III) and 25 ml 10% alcoholic potassium hydroxide were heated 6 hours on a water bath. The alcohol was then distilled off with steam, the residue in the flask was diluted with water, and the aqueous solution was cooled and acidified with dilute sulfuric acid. Acid (IIIA) came down and was filtered off and recrystallized from a mixture of acetone and benzene. Yield 0.8 g (88.5%). M. p. 257-259° (decomp.).

Found %: C 84.26; H 5.55. $C_{22}H_{16}O_2$. Calculated %: C 84.56; H 5.16.

7. 1,2,3,4-Dibenzo-7-methylfluorenone (VI). On the analogy of (IA), acid (IIIA) was converted by Kölsch's method [3] into (VI). 1 g of (IIIA) gave 0.65 g of (VI) with m. p. 201-203° (from glacial acetic acid).

Found %: C 89.70; H 5.08. $C_{22}H_{14}O$. Calculated %: C 89.77; H 4.79.

SUMMARY

1. It was shown that condensation of ethyl diazoacetate with 9-phenyl-9-bromofluorene in presence of copper sulfate leads to formation of the ethyl ester of 9-phenylphenanthrene-10-carboxylic acid. The process involves expansion of the five-membered fluorene ring to a six-membered ring.

2. It was shown that the reaction between ethyl diazoacetate and 9-(p-tolyl)-9-bromofluorene goes in two directions: 1) with ring expansion and formation of the ethyl ester of 9-(p-tolyl)-phenanthrene-10-carboxylic acid; 2) with migration of the tolyl group and formation of the ethyl ester of α-(p-tolyl)-β,β-diphenyleneacrylic acid.

3. Compounds prepared for the first time are: the ethyl esters of 9-phenyl- and 9-(p-tolyl)-phenanthrene-10-carboxylic acids; 9-(p-tolyl)-phenanthrene-10-carboxylic acid; α-(p-tolyl)-β,β-diphenyleneacrylic acid; 1,2,3,4-dibenzo-7-methylfluorenone and 9-(p-tolyl)-9-bromofluorene.

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* The crystals were evidently p-toluic acid which could have been formed from p-tolylformic acid by the action of excess oxidant. Due to its small quantity, the acid could not be isolated.

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THE CHEMISTRY OF FREE RADICALS OF THE HYDRAZINE SERIES

II. SYNTHESIS AND PROPERTIES OF α-BIPHENYL-α-PHENYL-β-PICRYLHYDRAZYL AND ITS HALOGENATED DERIVATIVES

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Previous studies [1, 2] applying the method of electron paramagnetic resonance established that the unpaired electron at the nitrogen atom of halogen derivatives of the stable free radical α,α-biphenyl-β-picryl-hydrazyl in the crystalline state has a smaller exchange interaction than the unpaired electron of the unsubstituted radical (I, X = H).

Exchange interaction of an unpaired electron is known to be characterized by the shape of the paramagnetic resonant absorption curve [1, 3]. The narrower this curve is, i.e., the smaller the value of ΔH, the larger the exchange interaction. Conversely, the broader the paramagnetic resonant absorption curve, i.e., the larger the value of ΔH, the smaller is the exchange interaction. An especially small exchange interaction was observed in the case of the fluoro derivative (I, X = F). This indicated that the unpaired electron of this radical was less labile than the one in the unsubstituted radical [2].

We thought it would be interesting to establish what influence was exerted by halogen atoms (Cl, Br) on exchange interaction when the halogen atom was in the 4 position of the biphenyl residue of radical (II).

With this objective, we synthesized compounds (IIa), (IIb), and (IIc).

(I)
(X = Cl, Br, F)

(IIa) X = H; (IIb) X = Cl; (IIc) X = Br.
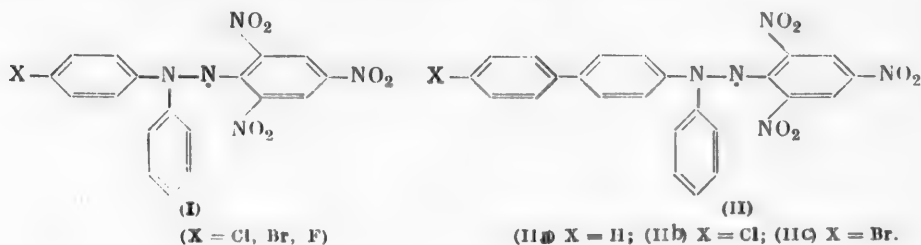
These radicals, which have not been described in the literature, were obtained by the following sequence of reactions:

$-CO_2$ → X—⟨ ⟩—⟨ ⟩—NH | C_6H_5 —HNO_2→ X—⟨ ⟩—⟨ ⟩—N—NO | C_6H_5 →

(V)   (VI)

—H_2→ X—⟨ ⟩—⟨ ⟩—N—NH_2 | C_6H_5 —picroylchloride→

(VII)

⋯→ X—⟨ ⟩—⟨ ⟩—N—NH—⟨NO_2 ... NO_2 ... —NO_2⟩ | C_6H_5 —PbO_2→

(VIII)

⟶ X—⟨ ⟩—⟨ ⟩—N—N·—⟨NO_2 ... NO_2 ... —NO_2⟩ | C_6H_5

(II)
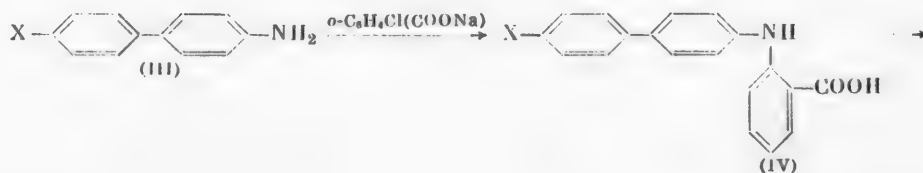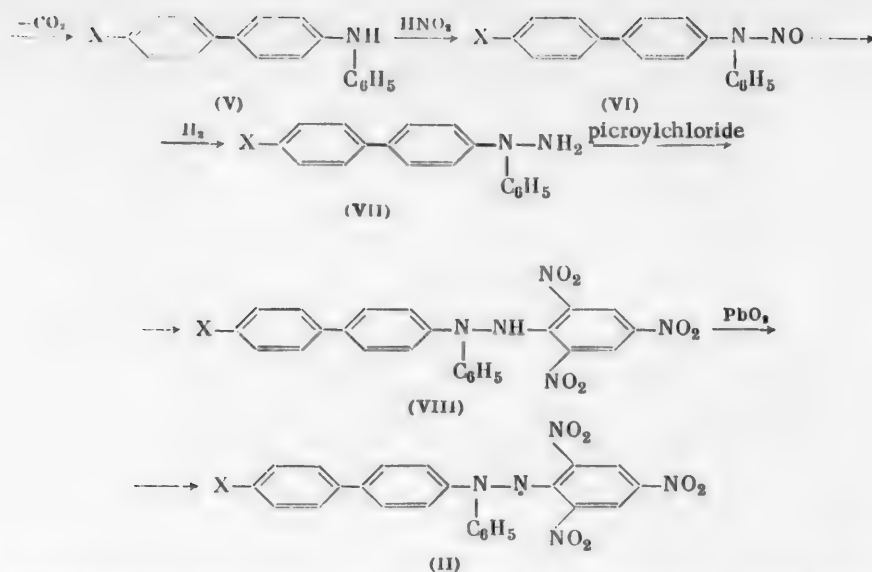
The new radicals (II) are perfectly stable compounds which do not alter in the air in the course of many months. They crystallize from a mixture of chloroform and ether in the form of nearly black prisms. The radicals dissolve in aromatic hydrocarbons and chloroform with a dark-violet color.

The unsubstituted radical (IIa) possesses characteristic properties. It is obtained by oxidation of the unsubstituted picrylhydrazine (VIII) in two forms. After conclusion of the oxidation reaction, the chloroform — ether solution at first deposits radical (IIa) in the form of nearly black prisms with m. p. 90-91° (yield 10-15%); after a few hours' standing in the cold, the filtrate deposits a finely crystalline brown substance with m. p. 160 to 161° (yield 25-30%). The latter dissolves in chloroform — ether with the same dark-violet color as the radical with m. p. 90-91°; after concentration, the solution at first deposits crystals of the radical with m. p. 90-91° followed (after standing in the cold) by a fresh crop of product with m. p. 160-161°.

Elemental analysis of the black and brown products reveals the same empirical composition. Their free-radical character was demonstrated by study of the electron paramagnetic resonance of these crystals, but they were also shown by the same technique to differ in crystal structure (their ∆H values are different — indicative of the greater exchange interaction of the brown product).

Reduction of the products with m. p. 160-161° and 90-91° by hydroquinone in chloroform — alcohol mixture gave the same red hydrazine with m. p. 165-167°. This was identical with the original hydrazine.

The black and brown radicals therefore possess the same skeletal structure. Later studies may show whether the products are different crystallographic modifications of a single substance or whether their difference resides in stereostructural characteristics or whether another factor is involved.

Results of electron paramagnetic resonance measurements* on the prepared compounds are presented in Table 1 (∆H values of the corresponding phenyl derivatives are set forth for comparison).

According to the tabulated data, α-biphenyl-α-phenyl-β-picrylhydrazyl (IIa) has much smaller exchange interactions than α,α-diphenyl-β-picrylhydrazyl (I, X = H). The same picture is also observed for the chloro and bromo derivatives of radicals (I) and (II). In the case of the bromo derivatives the ∆H for the biphenyl series (IIc) was considerably smaller (1.28) than the ∆H of the p-bromo derivative of the phenyl series (I, X = Br, ∆H = = 2.2). It is particularly noteworthy that the ∆H for the biphenyl radicals (I) increases on passage from the unsubstituted radical to radicals in which X = Cl or Br to a considerably greater extent than the values for the corresponding phenyl radicals (I).

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* Measurements were made by A. K. Chirkov by the method described in [4].

At first, one may suggest that these results are associated with a noncoplanar structure of the biphenyl residues in radicals (I) which would hinder the transmission of a reciprocal effect and would also hinder inter-molecular interaction. But since the electronic paramagnetic resonance was investigated in crystalline radicals, it would be premature to answer this query in the affirmative at the present stage. The hypothesis requires checking by x-ray analysis.

TABLE 1

| X | ΔH oerst. | |
	Radicals of the phenyl series (I)	Radicals of the biphenyl series (II)
H	1.0 ± 0.15	1.11 ± 1.01
Cl	1.2 ± 0.15	1.22 ± 0.01
Br	2.2 ± 0.15	1.28 ± 0.01

In all probability the system of biphenyl in itself, even if it had a coplanar structure, would transmit the influence of the substituents across two nuclei more weakly than across phenyl (in particular the inductive effect of halogen atoms). It is also known that the electronic density of the unpaired electron of the hydrazyl (I) is not distributed throughout the whole of the molecule but is concentrated mainly at the two nitrogen atoms of the hydrazyl group; in other words, the effect of the conjugation of the unpaired electron with the π-electrons of the rings is small in itself and becomes so small in the biphenyl system that it no longer appreciably influences the magnitude of ΔH.

Further insight into the causes of the attenuation of the influence of halogen atoms on passing from halogenated derivatives of radicals (I) to halogenated derivatives of radicals (II) will call for further investigations, for example of the electron paramagnetic resonance of fluorene analogs of radicals (I) and (II) with a constrained coplanar structure. Studies of the radicals in solutions are also necessary.

EXPERIMENTAL

1. Biphenylphenylamine and p-(X)-biphenylphenylamine-o-carboxylic acids (IV). A mixture of 0.1 mole biphenylamine [or p-(X)-biphenylamine], 0.1 mole sodium o-chlorobenzoate and 0.1 mole anhydrous potassium carbonate was boiled in isoamyl alcohol in presence of 0.2-0.3 g copper powder for 5-6 hours. After completion of the reaction, the isoamyl alcohol was distilled off with steam. Hydrochloric acid (d 1.19) was added to the residue until the reaction was acidic (to Congo). The greenish precipitate was suction-filtered. Crystallization from benzene gave nearly colorless needles. Biphenylphenylaminecarboxylic acids are readily soluble in ether, hot benzene and dioxane; sparingly soluble in alcohol, insoluble in water.

Analytical data and properties of the prepared compounds (IV) to (VII) are presented in Table 2.

2. Decarboxylation of biphenylphenylamine-o-carboxylic acid and p-(X)-biphenylphenylamine-o-carboxylic acids to the corresponding biphenylphenylamines (V). Biphenylphenylamine and p-(X)-biphenylphenylamines were prepared by decarboxylation of the corresponding biphenylphenylcarboxylic acids by heating to 10-15° above their melting points. Heating was continued until bubbles of carbon dioxide ceased to come off. The resulting oil solidified on cooling to a crystalline monolith. Recrystallization from alcohol gave colorless crystals, readily soluble in dioxane, chloroform and ether, soluble with difficulty in alcohol. The product gave a dark-blue coloration with a mixture of concentrated sulfuric and nitric acids. Unsubstituted biphenylphenylamine has been described [6]. The product that we obtained by the above procedure had a melting point agreeing with that of the product described in the literature.

3. Nitrosation of biphenylphenylamines (V) to nitrosamines (VI). Double the quantity of hydrochloric acid was added to a solution of 0.02 mole biphenylphenylamine or (X)-biphenylphenylamine in a 4:1 mixture of alcohol and dioxane. An aqueous solution of 0.04 mole sodium nitrite was added at 0-2°. The nitrosoamine came down in the form of a light-green precipitate when the liquid was diluted with water and strongly cooled. The crystalline product was grey-white after crystallization from ligroine. Insoluble in benzene, sparingly soluble in hot alcohol, easily soluble in ether, dioxane and hot ligroine. Under the action of concentrated hydrochloric

TABLE 2

Properties and Results of Analyses of Compounds (IV) - (VII)

Structure	Sub-stituent X	Name	Yield (in %)	Appearance of crystals under microscope	Melting point	Empirical formula	N (in %) found	N (in %) calc.
(IV)	H	Biphenylphenylamine-o-carboxylic acid	63	Greenish needles	250—255°	$C_{19}H_{15}O_2N$	4.95	4.84
	Cl	p-Chlorobiphenylphenylamine-o-carboxylic acid	55—60	Colorless needles	237—240	$C_{19}H_{14}O_2NCl$	4.18	4.33
	Br	p-Bromobiphenylphenylamine-o-carboxylic acid	60—65	Greenish needles	240—245	$C_{19}H_{14}O_2NBr$	3.99	3.80
(V)	H	Biphenylphenylamine	79	Colorless needles	110—112	$C_{18}H_{15}N$	5.69	5.71
	Cl	p-Chlorobiphenylphenyl-amine	75	Colorless, fine prisms	149—150	$C_{18}H_{14}NCl$	5.12	5.01
	Br	p-Bromobiphenylphenylamine	75	The same	142—145	$C_{18}H_{14}NBr$	4.61	4.33
(VI)	H	N-Nitrosobiphenylphenylamine	55—60	Grey plates	117—118	$C_{18}H_{14}ON_2$	10.37	10.21
	Cl	N-Nitroso-p-chlorobiphenylphenyl-amine	60	Yellow plates	110—112	$C_{18}H_{13}ON_2Cl$	9.25	9.09
	Br	N-Nitroso-p-bromobiphenylphenyl-amine	60	Small yellow needles	105—107	$C_{18}H_{13}ON_2Br$	8.19	7.93

TABLE 2 (Continued)

Structure	Substituent X	Name	Yield (in %)	Appearance of crystals under microscope	Melting point	Empirical formula	N (in %) found	N (in %) calc.
	H	α-Biphenyl-α-phenylhydrazine	25—30	Colorless needles	97—98	$C_{18}H_{16}N_2$	10.45	10.76
(VII)	Cl	α-(p-Chlorobiphenyl)-α-phenyl-hydrazine	30	Colorless lustrous plates	133—135	$C_{18}H_{15}N_2Cl$	9.77	9.50
	Br	α-(p-Bromobiphenyl)-α-phenyl-hydrazine	25—30	Light-yellow plates	125—127	$C_{18}H_{15}N_2Br$	8.39	8.25
	H	α-Biphenyl-α-phenyl-(p-nitro-benzylidene)-hydrazone	quanti-tative	Blood-red needles	123—125	$C_{25}H_{19}O_2N_3$	11.01	10.68
(VII)*	Cl	α-(p-Chlorobiphenyl)-α-phenyl-(p-nitrosobenzylidene)-hydrazone	The same	Clusters of orange crystals	151—153	$C_{25}H_{18}O_2N_3Cl$	9.75	9.83
	Br	α-(p-Bromobiphenyl)-α-phenyl-(p-nitrobenzylidene)-hydrazone	» »	Brick red prisms	161—162	$C_{25}H_{18}O_3N_3Br$	8.99	8.89

* p-Nitrobenzylidenehydrazones (VII).

acid, after brief standing, the solution acquires a light-green color; with concentrated sulfuric acid the color is dark-green.

4. Reduction of N-nitrosobiphenylphenylamines to hydrazines (VII). To a solution of 0.02 mole nitroso-amine (VI) in a 4:2 mixture of alcohol and dioxane was added 1.5 times the quantity of zinc dust [calculated on the weight of (VI)]. Glacial acetic acid was added in small portions at − 4 to 0° with vigorous stirring. The reaction was considered at an end when a drop of the solution was not colored green by concentrated hydrochloric acid. Thereupon, the reaction mixture was heated to 30-40° and suction-filtered from sludge. The hydrazine was brought down from the filtrate by addition of water. Colorless crystals from alcohol. The hydrazines are easily soluble in hot alcohol, chloroform and ether, insoluble in hot water. They dissolve in concentrated sulfuric acid with a dark-blue color.

5. Preparation of the hydrazones of biphenylphenylhydrazines. The hydrazines were characterized in the form of their hydrazones with p-nitrobenzaldehyde, which were obtained in quantitative yield. Properties and analyses of the hydrazones are given in Table 2.

6. α-Biphenyl-α-phenyl- and α-[p-(X)-biphenyl]-α-phenyl- β-picrylhydrazines (VIII). 0.05 mole picryl chloride in chloroform was added to a solution of 0.1 mole biphenylphenylhydrazines (VII) in chloroform. The reaction mixture at once turned red. After standing for a short period on ice, the mixture deposited the colorless hydrochloride of α-[p-(X)-biphenyl]-α-phenylhydrazine. The precipitate was separated and the filtrate evaporated to $\frac{1}{3}$ of its original volume. The concentrated chloroform solution was diluted with double its volume of hot alcohol. On cooling, the reaction mixture deposited blue crystals which were then suction-filtered and crystallized from a 1:2 mixture of chloroform and alcohol or from a mixture of alcohol and acetic acid. The crystals of picrylhydrazines are easily soluble in chloroform and dioxane, poorly soluble in alcohol.

7. Oxidation of α-biphenyl-α-phenyl- and α-[p-(X)-biphenyl]-α-phenyl- β-picrylhydrazines (VIII) to radicals (II). a) Oxidation of α-biphenyl-α-phenyl-β-picrylhydrazine to α-biphenyl-α-phenyl-β-picrylhydrazyl. To a solution of 0.05 mole biphenylphenylpicrylhydrazine in dry chloroform was added 10 times its weight of lead peroxide and 0.5 mole anhydrous sodium sulfate. Thereupon, the reaction mixture was shaken for 1-1.5 hours. The dark-violet solution was suction-filtered from slurry and filtered in a column through a bed of Al_2O_3. The chloroform was then driven off in vacuo to 1.5 times its original volume. To the residue was added double its volume of dry ether. On cooling (− 5 to 0°) the solution deposited black crystals (10-15% yield) which were separated. The mother liquor was stood for 10-12 hours at 3-5° and deposited a brown substance (25-30%). This was dissolved in 1:2 chloroform − ether and rapidly cooled; the solution at first deposited a black substance; the filtrate from the latter was stood for 10-12 hours and deposited the brown substance.

Both the black and the brown product are readily soluble in chloroform, benzene and toluene, poorly soluble in ether, and sparingly soluble in alcohol. Under the action of an alcoholic solution of hydroquinone, the black and brown radicals (in chloroform solutions) are very quickly reduced to the original α-biphenyl-α-phenyl-β-picrylhydrazine. Oxidation of the resulting picrylhydrazine by lead peroxide, under the conditions described above, led to re-formation of the black and brown products.

b) Oxidation of α-[p-(X)-biphenyl]-β-phenylpicrylhydrazines to α-[p-(X)-biphenyl]-α-phenyl-β-picryl-hydrazyls (II). p-Chloro- and p-bromo derivatives of α-biphenyl-α-phenyl-β-picrylhydrazine were oxidized under the above conditions with ten times their weight of lead peroxide.

After suction-filtration from slurry, the chloroform solutions of the hydrazyl were chromatographed over Al_2O_3, and the radical was isolated by distillation of the chloroform in vacuo and by addition to the residue of double the volume of ether. After standing for 8-10 hours at 5-6°, the ether-chloroform solution deposited the black radical. The radicals were extremely soluble in chloroform, benzene and toluene, very poorly soluble in alcohol and ether. An alcoholic solution of hydroquinone smoothly converts the radicals into chloroform solution into the original picrylhydrazines.

Analytical data and properties of hydrazines (VII) and radicals (II) are set forth in Table 3.

TABLE 3

Properties and Results of Analyses of Hydrazines (VIII) and Hydrazyls (II)

Structure	Substituent X	Name	Yield (in %)	Form of crystals under microscope	Melting point	Empirical formula	Found (%)			Calculated (%)		
							C	H	N	C	H	N
(VIII)	H	α-Biphenyl-α-phenyl-β-picrylhydrazine	65	Brick-red, elongated plates	165—167°	$C_{24}H_{17}O_6N_5$	61.35	3.54	15.06	61.14	3.64	14.86
	Cl	α-(p-Chlorophenyl)-α-phenyl-β-picrylhydrazine	68	Brown needles	172—175	$C_{24}H_{16}O_6N_5Cl$	57.27	3.33	13.91	57.01	3.16	13.86
	Br	α-(p-Bromodiphenyl)-α-phenyl-β-picrylhydrazine	65	Light-brown plates	180—181	$C_{24}H_{16}O_6N_5Br$	52.23	3.01	12.69	52.36	2.9	12.72
	H	α-Biphenyl-α-phenyl-β-picrylhydrazyl (brown)	25—30	Fine brown prisms	160—161	$C_{24}H_{16}O_6N_5$	61.45	3.68	14.54	61.27	3.40	14.89
	H	α-Biphenyl-α-phenyl-β-picrylhydrazyl (black)	10—15	Dark-blue prisms	90—91	$C_{24}H_{16}O_6N_5$	61.02	3.52	14.82	61.27	3.40	14.89
(II)	Cl	α-(p-Chlorobiphenyl)-α-phenyl-β-picrylhydrazyl	45—50	Very fine and nearly black prisms	171—173	$C_{24}H_{15}O_6N_5Cl$	—	—	13.74	—	—	13.89
	Br	α-(p-Bromobiphenyl)-α-phenyl-β-picrylhydrazyl	40—50	Nearly black prisms	165—166	$C_{24}H_{15}O_6N_5Br$	—	—	12.42	—	—	12.74

SUMMARY

1. The following radicals of the hydrazine series, not previously described in the literature, were synthesized: α-biphenyl-α-phenyl-β-picrylhydrazyl (IIa) and its chloro and bromo derivatives (IIb, IIc).

2. It was established by electron paramagnetic resonance data that the exchange interaction of the unpaired electron of biphenyl radicals (in the crystalline state) is increased to a lesser extent on transition from the unsubstituted radical to a substituted one than is the case for the corresponding phenyl radicals. It follows from these results that the biphenyl residue in the investigated radicals (II) in the crystalline state transmits the influence of halogen atoms to a lesser extent than the phenyl in radicals (I).

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THE SYNTHESIS OF NEROLIDOL, METHYLNEROLIDOL, FARNESAL
AND METHYLFARNESAL

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Several publications of recent years have described the synthesis of terpenic compounds of interest in perfumery. Intermediates in these syntheses were geranyl chloride (I) [8-chloro-2,6-dimethyl-2,6-octadiene] and methylgeranyl chloride (II) [8-chloro-2,3,6-trimethyl-2,6-octadiene] [1-5].

Taking into account the existence of these convenient syntheses of the chlorides in question and the probability of manufacture of these products in the near future on the factory scale, we made use of chlorides (I) and (II) for synthesis of nerolidol (V) [2,6,10-trimethyl-2,6,11-dodecatrien-10-ol], methylnerolidol (VI) [2,3,6,10-tetramethyl-2,6,11-dodecatrien-10-ol], and the following aldehydes: farnesal (VII) [2,6,10-trimethyl-2,6,10-dodecatrien-11-al] and methylfarnesal (VIII) [2,3,6,10-tetramethyl-2,6,10-dodecatrien-11-al]. The following reactions were involved:

$$\underset{H_3C}{\overset{H_3C}{>}}C=\underset{\underset{R}{|}}{C}CH_2CH_2\underset{\underset{CH_3}{|}}{C}=CHCH_2Cl \xrightarrow[\text{and ketonic cleavage}]{[CH_3COCHCOOC_2H_5]Na}$$

(I) R = H
(II) R = CH$_3$

$$\longrightarrow \underset{H_3C}{\overset{H_3C}{>}}C=\underset{\underset{R}{|}}{C}CH_2CH_2\underset{\underset{CH_3}{|}}{C}=CHCH_2CH_2COCH_3 \xrightarrow[\text{and hydrolysis}]{CH_2=CHMgBr}$$

(III) R = H
(IV) R = CH$_3$

$$\longrightarrow \underset{H_3C}{\overset{H_3C}{>}}C=\underset{\underset{R}{|}}{C}CH_2CH_2\underset{\underset{CH_3}{|}}{C}=CHCH_2CH_2\underset{\underset{CH_3}{|}}{C}(OH)CH=CH_2 \longrightarrow$$

(V) R = H
(VI) R = CH$_3$

$$\longrightarrow \underset{H_3C}{\overset{H_3C}{>}}C=\underset{\underset{R}{|}}{C}CH_2CH_2\underset{\underset{CH_3}{|}}{C}=CHCH_2CH_2\underset{\underset{CH_3}{|}}{C}=CHCHO$$

(VII) R = H
(VIII) R = CH$_3$
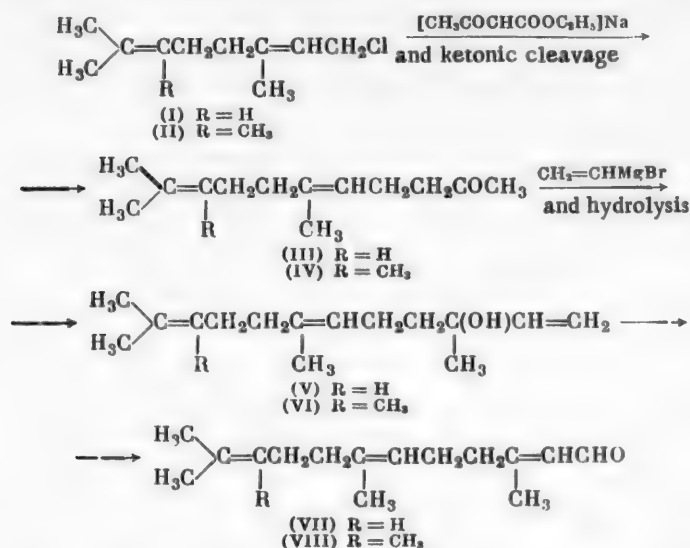
Formation of geranylacetone (III) [2,6-dimethyl-2,6-undecadien-10-one] by reaction of geranyl chloride with ethyl acetoacetate has been described in [5, 6]. We carried out the preparation of geranylacetone and of methylgeranylacetone (IV) [2,3,6-trimethyl-2,6-undecadien-10-one] without separation of the substituted acetoacetic esters from the reaction mixture. We converted ketones (III) and (IV) into tertiary alcohols (V) and (VI) by reacting these ketones with vinylmagnesium bromide. A most convenient method of preparation of the latter was recently developed by Norman [7]. Passage from tertiary alcohols (V) and (VI) to aldehydes (VII) and (VIII) was effected by allylic rearrangement and by oxidation with chromic acid mixture by the usual procedure for such transformations. The constants of the specimens of nerolidol and farnesal that we prepared were the

same as those described in the literature. Methylnerolidol and methylfarnesal have not previously been described.

<center>EXPERIMENTAL</center>

1. Preparation of Geranylacetone and Methylgeranylacetone

The starting chlorides had the following characteristics: geranyl chloride, prepared by reaction of linalool with phosphorus trichloride [8], had b. p. 80.5-83.5° (4-5 mm), $n^{20}D$ 1.4772, d^{20}_4 0.9258, and Cl 20.7% (by hydrolysis); methylgeranyl chloride, prepared by reaction of 2,3-dimethyl-1,3-butadiene hydrochloride with isoprene [4], had b. p. 76-78° (2 mm), $n^{20}D$ 1.4818, d^{20}_4 0.9305, and 18.2% Cl (by hydrolysis).

0.65-0.7 mole ethyl acetoacetate was put into a three-necked flask fitted with stirrer, dropping funnel and reflux condenser. The stirrer was started and 0.33-0.36 g-atom metallic sodium was added in portions. Unreacted sodium was bound by addition of 40-50 ml anhydrous alcohol. To the resulting sodium ethyl aceto-acetate, after cooling to room temperature, was added 0.32-0.35 mole of terpenic chloride dropwise with stirring. The mixture was thereupon stirred for another 3 hours at 85-90°. The content of the flask was then poured into 1 liter of 10% aqueous potassium hydroxide; the mass was then stirred about 5 hours at room temperature, heated to 80-90°, and left to cool; it was then neutralized with hydrochloric acid (Congo test) and the ketone was distilled off with steam.

From 60.54 g (0.35 mole) geranyl chloride was obtained 30.57 g (45%) geranylacetone after two distillations in vacuo.

B. p. 100.5-101.5° (2.5-3 mm), $n^{20}D$ 1.4633, d^{20}_4 0.8695, MR_D 61.49. $C_{13}H_{22}OF_2$. Calculated 61.34.

Semicarbazone: m. p. 94-95° (from alcohol).

Found %: N 16.71, 17.01. $C_{14}H_{25}ON_3$. Calculated %: N 16.72.

Literature data: b. p. 125-133° (12 mm) [6]; b. p. 141-143° (13 mm), n D 1.46303, d^{23} 0.871; semi-carbazone, m. p. 95-96° [9]; b. p. 136-138° (10 mm), $n^{20}D$ 1.469, d^{20}_4 0.8812 [10]; b. p. 124° (10 mm), $n^{23}D$ 1.465; semicarbazone, m. p. 92-93° [11].

A similar procedure, starting from 60 g (0.32 mole) methylgeranyl chloride, gave 23.4-30.1 g (35-45%) methylgeranylacetone after two distillations in vacuo.

B. p. 100-101° (1-2 mm), $n^{20}D$ 1.4718, d^{20}_4 0.8805, MR_D 66.23. $C_{14}H_{24}OF_2$. Calculated 65.93.

Semicarbazone, m. p. 131-132° (from aqueous alcohol).

Found %: N 15.85, 15.96. $C_{15}H_{27}ON_3$. Calculated %: N 15.83.

Literature data: b. p. 105-107° (2 mm), $n^{19}D$ 1.4702; semicarbazone, m. p. 101-102° and 138-139° [12].

2. Preparation of Nerolidol and Methylnerolidol

The apparatus for carrying out the Norman reaction comprised a three-necked flask for preparation of vinyl bromide, fitted with stirrer, dropping funnel and reflux condenser, and a four-necked flask for preparation of vinylmagnesium bromide, fitted with stirrer, dropping funnel (with end extending nearly to the bottom of the flask), reflux condenser (with the upper end protected by a calcium chloride tube), and a thermometer.

Into the three-necked flask was charged 50-100 g sodium hydroxide, and methyl alcohol was added in quantity sufficient to cover the surface of the alkali. The stirrer was put in motion. As soon as the mixture had formed a slurry, 140 g of dibromoethane was added dropwise at a water-bath temperature of 70-80°. The result-ing vinyl bromide passed through the condenser in which the water was at room temperature, through an empty bottle, through a bottle containing distilled water, and through a calcium chloride-containing U-tube. It then entered a dropping funnel, cooled with a mixture of dry ice and acetone, into which 25 ml absolute tetrahydro-furan had been charged beforehand.

Into the four-necked flask were put 7 g magnesium turnings activated with a trace of iodine, 1 ml ethyl bromide and 50 ml absolute tetrahydrofuran. The flask contents were heated to 30° and the mixture of vinyl bromide and tetrahydrofuran was gradually introduced. After the reaction had started, the stirrer was put in motion and dropwise addition of the vinyl bromide was continued while the temperature of the reaction mixture was held at 40-50°. After the whole of the vinyl bromide had been added, the mixture was stirred one hour at 55-60° and cooled to −20°; 75 ml absolute ether was then run in. A mixture of 29 g geranylacetone in 10 ml absolute tetrahydrofuran and 20 ml absolute ether was added at a temperature of −20 to −12°; stirring was continued at this temperature for another 3 hours and the mass was left overnight. The next day, the resulting suspension was heated 2 hours at 40-50°, cooled to room temperature and poured into a mixture of 250 g ice and 80 g ammonium chloride; the ether layer was separated and the aqueous layer was extracted four times with ether (total volume 250 ml). The combined ethereal extracts were dried with sodium sulfate and the solvent was distilled off. Vacuum distillation of the residue gave 17 g (51%) of nerolidol with b. p. 95-101° (1 mm).

Analysis was carried out on a narrow cut of the product with b. p. 99-101° (1 mm), $n^{20}D$ 1.4778, d^{20}_4 0.8759, MR_D 71.83. $C_{15}H_{26}OF_3$. Calculated 71.59.

Found %: C 80.86, 80.94; H 11.94, 11.82. $C_{15}H_{26}O$. Calculated %: C 81.03; H 11.78.

Literature data: b. p. 96-98° (0.2 mm), $n^{22}D$ 1.4786, d^{22}_4 0.8778 [6]; b. p. 94° (0.18 mm), $n^{20}D$ 1.4784, d^{20}_4 0.8752 [1].

Reaction on similar lines with 18.3 g methylgeranylacetone gave 11.4 g (50.7%) of methylnerolidol with b. p. 110-118° (1 mm).

Analysis was carried out on a narrow cut with b. p. 115-117° (1 mm), $n^{20}D$ 1.4798, d^{20}_4 0.8826, MR_D 76.05. $C_{16}H_{28}OF_3$. Calculated 76.21.

Found %: C 81.56, 81.44; H 11.93, 12.03. $C_{16}H_{28}O$. Calculated %: C 81.29; H 11.94.

3. Preparation of Farnesal and Methylfarnesal

11.05 g nerolidol was dissolved in 25 ml glacial acetic acid. Thereupon a mixture of 10 g potassium dichromate, 12.5 g sulfuric acid and 250 ml water was added; the stirrer was started and the mixture was heated 15 minutes at 60-67°; after cooling, the oily layer was separated and the aqueous layer was extracted several times with ether (total volume 250 ml). The ethereal extracts were combined with the oily layer and washed with 5-10% sodium carbonate solution and with water, dried with anhydrous sodium sulfate, and distilled to give (after two distillations) 1.62 g farnesal.

B. p. 147-149° (10 mm), $n^{20}D$ 1.4861, d^{20}_4 0.8983, MR_D 70.43. $C_{15}H_{24}OF_3$. Calculated 70.08.

Semicarbazone, m. p. 125-127° (from alcohol).

Found %: N 15.32, 15.37. $C_{16}H_{27}ON_3$. Calculated %: N 15.14.

Literature data: b. p. 105-106° (3 mm), $n^{20}D$ 1.4871, d^{20}_4 0.8999; semicarbazone, m. p. 136° [10]; b. p. 172-174° (14 mm), nD 1.4995, d^{18} 0.893; semicarbazone, m. p. 133-135° [9]; b. p. 135-137° (1.7 mm), $n^{20}D$ 1.4980, d^{20}_4 0.8940; semicarbazone, m. p. 127.5-128° [13].

A similar experiment with 10.81 g methylnerolidol gave 1.34 g methylfarnesal after two distillations.

B. p. 120-121.5° (2 mm), $n^{20}D$ 1.4978, d^{20}_4 0.9094, MR_D 75.51. $C_{16}H_{26}OF_3$. Calculated 74.70. Aldehyde content 93.6% (by oximation).

Found %: C 81.69; H 10.86. $C_{16}H_{26}O$. Calculated %: C 81.99; H 11.18.

Semicarbazone, m. p. 133.5° (from alcohol).

Found %: N 14.15, 14.23. $C_{17}H_{29}ON_3$. Calculated %: N 14.41.

SUMMARY

Starting from geranyl chloride and methylgeranyl chloride, the sesquiterpenic alcohols nerolidol and methylnerolidol and the aldehydes farnesal and methylfarnesal were synthesized.

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POLAROGRAPHIC STUDY OF AZO DERIVATIVES OF BARBITURIC
AND THIOBARBITURIC ACIDS

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Narcotics and anticonvulsants which have long been employed in medical practice are derivatives of barbituric acid such as veronal, luminal and barbamyl. One of us [1] has already synthesized a series of azo derivatives of barbituric and thiobarbituric acids. Pharmacological tests showed that many of them also possess narcotic and anticonvulsant activity. A relation between the structure and physiological action of the derivatives was established.

In the present work we made a polarographic study of azo derivatives of barbituric and thiobarbituric acids in order to find a relation between the structure of the azo derivatives and their susceptibility to reduction. The latter was characterized by the magnitude of the half-wave potential at the dropping mercury electrode.

We know from [2-4] that azo compounds are easily reduced at the dropping mercury electrode. Their susceptibility to reduction depends on the chemical structure of the molecule. In the case of azobenzene and its derivatives it was demonstrated [5] that two electrons participate in the reduction and that the products of reduction are hydrazo compounds: $R-N=N-R_1 + 2H^+ + 2e^- \rightarrow RNH-NHR_1$.

Nga also arrived at a similar conclusion in a study of the reduction of orange (II) [6]. A number of investigations [3, 7, 8] indicate that the system azo compound — hydrazo compound is reversible in the majority of cases.

Experimental Procedure and Apparatus

A polarographic study of azo derivatives of barbituric and thiobarbituric acids was made with the help of a visual polarograph of the UFAN type. The current was measured with the help of a mirror galvanometer of the M-21/2 type with a sensitivity of about 10^{-9} amp/mm/m and with a large vibration period (T about 20 sec.). The cathode was a dropping mercury electrode immersed in the solution under test. The anode was a saturated calomel electrode.

All determinations were performed in a thermostat with a toluene thermoregulator at 25°.
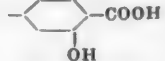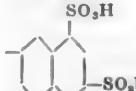
Azo derivatives with sufficient solubility in water were examined at a concentration of $1 \cdot 10^{-3}$ molar; sparingly soluble compounds (concentration less than 10^{-3} molar) were examined in saturated solution. The indifferent electrolyte was a buffer solution consisting of a mixture of 1 M NH_4Cl and 1 M NH_4OH. Gelatin (0.01%) was added to the solution since in its absence maxima appeared on the polarograms. Dissolved atmospheric oxygen was removed by passage of a stream of purified hydrogen for 10 minutes.

Experimental Results

In the present work we studied 14 azo derivatives of barbituric acid and 13 corresponding azo derivatives [*] of thiobarbituric acid with the general formula (A):

[*] All of the azo derivatives used in this work were synthesized by K. R. Voronova [1] under the guidance of L. P. Kulev, to whom we convey our thanks for making the preparations available for the investigation.

TABLE 1

Prep. No.	X	R	Angular wave coefficient b_k	$-\varphi_{1/2}$(mv)	K_s
1	O	(phenyl)	0.040	558	Satd. sol.*
2	S	The same	0.036	558	Satd. sol.
3	O	—⟨⟩—SO₃H	0.080	796	3.98
4	S	The same	0.041	578	2.89
5	O	—⟨⟩—COOH	0.083	694	Satd. sol.
6	S	The same	0.056	605	Satd. sol.
7	O	(phenyl with COOH)	0.047	578	Satd. sol.
8	S	The same	0.032	564	Satd. sol.
9	O	(phenyl with COOH)	0.076	713	Satd. sol.
10	S	The same	0.035	581	Satd. sol.
11	O	—⟨⟩—COOH, OH	0.048	618	3.5
12	S	The same	0.043	613	3.8
13	O	C₂H₅**—⟨⟩—COOH	0.073	668	Satd. sol.
14	S	The same	0.044	578	Satd. sol.
15	O	—⟨⟩—COOCH₂N(C₂H₅)₂	0.060	685	Satd. sol.
16	S	The same	0.051	588	Satd. sol.
17	O	(naphthyl)	0.092	596	Satd. sol.
18	S	The same	0.030	580	Satd. sol.
19	O	(naphthyl)—SO₃H	0.036	563	2.83
20	S	The same	0.033	568	2.85
21	O	(naphthyl)	0.050	658	Satd. sol.
22	S	The same	0.040	632	Satd. sol.
23	O	(naphthyl)—SO₃H	0.092	613	Satd. sol.
24	S	The same	0.031	595	3.9
25	O	(naphthyl) SO₃H, —SO₃H	0.066	594	Satd. sol.
26	S	The same	0.027	570	2.95
27	O	(naphthyl)—SO₃H	0.033	593	3.22

* Saturated solution.

** The C₂H₅ radical replaces hydrogen in the 5 position of barbituric acid.

$$XC \underset{NH-CO}{\overset{NH-CO}{<}} CH-N=N-R$$

(A)
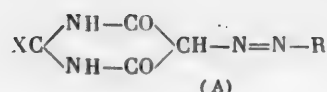
where X is oxygen in the case of barbituric acid, and sulfur in the case of thiobarbituric acid; R is phenyl, naphthyl, substituted phenyl (with sulfo group or carboxyl), sulfo-substituted naphthyl. Experimental results are presented in Table 1.

All of the potential values in the text, tables and diagrams relate to the saturated calomel electrode; the capillary characteristic $L = m^{2/3} \tau^{1/6}$ in the majority of the experiments was equal to 0.985.

The half-wave potentials, angular coefficients and diffusion current constants presented in Table 1 are mean values from three or more experiments. Deviations from the mean did not exceed ± 1 mv.

In the discussion of the experimental results (in the text, tables and diagrams), the full name of the azo derivative is replaced by its serial number in Table 1.

Evaluation of Results

We see from Table 1 that the half-wave potentials (h.w.p.) of all of the azo derivatives (except No. 3) are within the range of − 560 to − 700 mv. In the majority of cases the azo derivatives of thiobarbituric acid are reduced at more positive values of h.w.p. than the corresponding derivatives of barbituric acid, i.e., they are reduced more easily. Exceptions are Nos. 1 and 2, 11 and 12, and 19 and 20 (Table 1). These have substantially identical h.w.p. The difference in h.w.p. of the corresponding derivatives of barbituric and thiobarbituric acids containing naphthyl radicals is 15-25 mv (with exception of Nos. 19 and 20) (Table 2).

TABLE 2

No. of azo derivative	17, 18	19, 20	21, 22	23, 24	25, 26
$\Delta\varphi_{1/2}$ (mv)	16	(−5)	26	18	24

In the series of phenyl derivatives (Table 3) this difference is considerably larger and is equal to 90-130 mv (except for Nos. 1, 2, 7, 8, 11, and 12).

TABLE 3

No. of derivative	1, 2	3, 4	5, 6	7, 8	9, 10	11, 12	13, 14	15, 16
$\Delta\varphi_{1/2}$ (mv)	(0)	118	89	(14)	132	(5)	90	97

Since two electrons participate in the process of reduction of azo compounds to hydrazo compounds, the angular coefficient of the reversible wave at 25° must be equal to $b_k = 0.0592 : 2 = 0.0296 \approx 0.030$. In the case of an irreversible process associated with inhibition of the electrochemical reaction, the angular coefficient of the wave must be equal to $b_k = 0.030 : \alpha$, where α is less than 1 − the discharge coefficient (α is usually between 0.7 and 0.3). Consequently the angular coefficient of the irreversible two-electron wave must be larger than 0.030 and must be in the range of 0.040 to 0.10.

Inspection of the angular coefficients of the waves of the organic compounds in Table 1 indicates that most of the azo derivatives of thiobarbituric acid are reduced more reversibly than the corresponding derivatives

of barbituric acid. We see from Table 1 that in the case of derivatives of thiobarbituric acid the angular co-efficient of the wave varies between 0.027 and 0.056, and for half of the compounds (Nos. 2, 8, 18, 20, 24, and 26) the angular coefficient of the wave is less than 0.040; we can therefore assume that the electrode process is nearly completely reversible. Only in two cases (Nos. 19 and 27) is the angular coefficient of thiobarbituric acid derivatives less than 0.040; in the remaining cases it is more than 0.040 and the electrode process is accordingly irreversible.

The difference in h.w.p. recorded in Table 3 may be associated in some cases with the differing degrees of reversibility of the electrode process for azo derivatives of barbituric and thiobarbituric acids. One of us [9] has shown that when an irreversible electrode process is associated with inhibition of the process of discharge of ionization, the cathodic wave is shifted in the negative direction in comparison with a reversible wave, and its angular coefficient becomes larger than the theoretical value. The data of Tables 1 and 3 are in accord with these theoretical considerations. When the process is reversible, the h.w.p. is nearly identical in the two series of compounds (Nos. 19 and 20). It must be emphasized that only in the case of a reversible electrode process is the half-wave potential approximately equal to the standard oxidation − reduction potential of the system azo compound − hydrazo compound. In the case of an irreversible electrode process, the half-wave potential of the cathodic wave is more negative than the standard oxidation − reduction potential at a polarization value that depends on the magnitude of the exchange current [9]. Consequently, only when the electrode process is reversible does the half-wave potential directly characterize the equilibrium oxidation−reduction properties of the system.

On the basis of the foregoing discussion the influence of substituents in the azo derivatives listed in Table 1 on the h.w.p. can be twofold. The substituent can influence the equilibrium standard oxidation− reduction potential of the system azo compound − hydrazo compound, or it can influence the exchange current, i.e., the kinetics of the electrode process or the magnitude of the polarization. Decrease in the exchange current causes the half-wave potential of the cathodic wave to be shifted in the negative direction (and the anodic wave − in the case of an oxidation process − in the positive direction) [9].

In the case of a reversible process involving both of the compounds under comparison, the substituent only exercises the first of the above two effects. In the case of an irreversible process involving both compounds (or only one of the compounds under comparison) the influence of the substituent is exerted in both directions. Inspection of only the cathodic wave of an azo compound rules out the possibility of establishing the magnitudes of the shift of h.w.p. associated with each of the two effects of the substituent.

In the subsequent discussion of the influence of substituents on the h.w.p., our aim is to consider the over-all effect, i.e., the effect of substituents both on the equilibrium potential and on the exchange current (if the electrode process for one of the compared compounds is irreversible, i.e., the angular coefficient of the wave is greater than 0.040). When speaking about the inhibition of reduction in presence of a given substituent, we shall also be referring to the over-all effect. In this connection, it is entirely possible that the introduction of a substituent will shift the equilibrium standard oxidation − reduction potential (approximately equal to the reversible h.w.p.) in the positive direction, but the considerable decrease of the exchange current will overlap with this effect, and the net result will be that the irreversible h.w.p. of the substance will become more negative after introduction of the substituent.

In the series of naphthalenic derivatives of both barbituric and thiobarbituric acids, the introduction of the sulfo group shifts the h.w.p. to more positive values, i.e., it facilitates reduction (as evident from comparison of the h.w.p. of Nos. 17 and 19, 18 and 20, 21 and 23, 22 and 24). The influence of the sulfo group on the h.w.p. is greater if it is in the 7 position (Fig. 1, 27 and 23). Introduction of a second sulfo group makes the potential even more positive (Fig. 1, 21, 23, 25 and 22, 24, 26). This effect of the sulfo group is fully consistent with literature data according to which the introduction of a sulfo group facilitates reduction of compounds at the dropping mercury electrode [2, 4, 10].

Another picture is observed in the case of benzene derivatives. Introduction of a sulfo group into the benzene ring causes the h.w.p. to become more negative, i.e., reduction is hindered (compare Nos. 1 and 3, 2 and 4). In the light of the theoretical considerations put forward above, the following explanation of the difference in the effect of the sulfo group in the naphthalene and benzene derivatives may be advanced. The sulfo group is an electron acceptor and its introduction into azo compounds must weaken the double bond of

−N = N− with consequent shift of the equilibrium oxidation − reduction potential in the positive direction. This effect evidently predominates in the naphthalene derivatives. The behavior of the azo derivatives of thiobarbituric acid Nos. 18 and 20 illustrates this fact with particular clarity. Both of these compounds are reduced irreversibly so that the h.w.p. shift is equal to the equilibrium potential shift; this shift occurs in the positive direction. Similar considerations are applicable to compounds Nos. 22, 24 and 26; these are likewise reduced reversibly. The corresponding naphthalene derivatives of barbituric acid are reduced sometimes irreversibly (Nos. 17, 21, 23, 25) and sometimes reversibly (Nos. 19, 27). Nevertheless, they still obey the same law (shift of the h.w.p. in the positive direction on introduction of a sulfo group). This indicates that the exchange current is small, and hence the second effect (h.w.p. shift in the negative direction due to decrease in exchange current) is small and the first effect predominates.
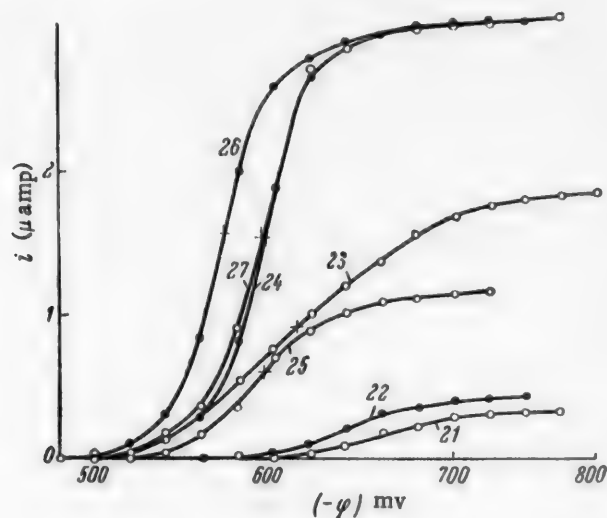
Fig. 1. Explanation in text.

The h.w.p. shift toward the negative side when a sulfo group enters a benzene derivative of barbituric acid can be explained on the assumption of predominance of the exchange current reduction effect. Comparison of compounds Nos. 1 and 3 actually shows that the strong h.w.p. shift in the negative direction (by 236 mv) on introduction of a sulfo group is accompanied by an increase of the angular coefficient of the wave from the value for a nearly reversible process (0.040) to the value for an irreversible process (0.080).
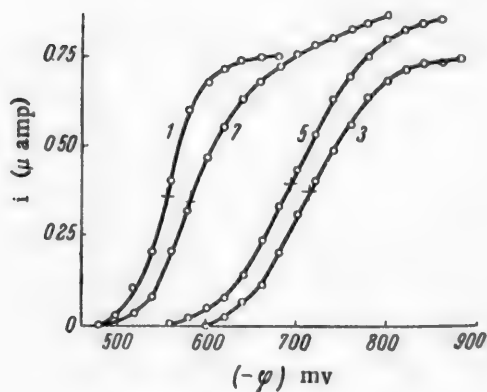
Fig. 2. Explanation in text.

The following question may be asked: How can one reconcile the weakening of the chemical bond (accompanying the equilibrium oxidation−reduction potential shift to the positive potential side) with decrease in the exchange current, i.e., with increase of the energy of activation of the discharge process? It is easily seen, however, that no contradiction is involved here because the activation energy during discharge of a molecule at an electrode depends not only on the bond energy but also in general on the structure of the molecule; broadly speaking it depends on the ease and the closeness of approach to the electrode surface of the atomic grouping participating in the electrode process. Introduction of a substituent can simultaneously weaken the chemical bond and increase the activation energy of the electrode process (i.e., decrease the exchange

current) due to the development, for example, of supplementary steric hindrance in the course of the electrode reaction.

Introduction of a carboxyl group into the benzene ring of the azo derivatives under consideration causes the h.w.p. to become more negative, i.e., reduction becomes more difficult. The influence of the carboxyl group depends on its position in the benzene ring (Table 4, Fig. 2).

TABLE 4

Position		9,10 (ortho)	7,8 (meta)	5,6 (para)
$\Delta \varphi_{1/2}$	$\begin{cases} O \\ S \end{cases}$	158 23	20 6	136 47

We see from Table 4 that in the case of derivatives of barbituric acid the greatest effect is exercised by a carboxyl group in the ortho-position relative to the azo group; in the case of thiobarbituric acid derivatives the greatest effect is exercised by the carboxyl group in the para-position. In both groups of compounds a meta carboxyl group has a weaker effect.

There are indications in the literature that the introduction of a carboxyl group into a polarographically active molecule leads to a h.w.p. shift toward the positive side, i.e., to greater ease of reduction of the compound at the dropping mercury electrode [1, 2]. Our own experimental data are at variance with these literature data. It could well be thought that such an effect of the carboxyl group is associated with an irreversible electrode process. Judging by the angular coefficients of the waves of compounds 2, 8, 10, and 12, all of these compounds are reduced reversibly; nevertheless a carboxyl group shifts the h.w.p. in the negative direction. We therefore suggest that the carboxyl group in the benzene derivatives under investigation manifests electron-donating properties and strengthens the $-N=N-$ bond. This differing behavior of the group in different compounds is not inconsistent with modern concepts of the reciprocal influence of atoms. Numerous examples show that the magnitude and character of atomic interaction is determined not only by the nature of the group but also by the structure of the whole of the remaining molecule.

Introduction of an ethyl radical into the 5 position of barbituric (or thiobarbituric) acid makes the h.w.p. more positive (Nos. 5 and 13, 6 and 14). Esterification of the carboxyl group has a similar effect (Nos. 5 and 15, 6 and 16).

SUMMARY

1. Fourteen azo derivatives of barbituric acid and thirteen corresponding azo derivatives of thiobarbituric acid were studied. It was established that azo derivatives of thiobarbituric acids are reduced more reversibly than the corresponding azo derivatives of barbituric acid.

2. Introduction of a sulfo group facilitates reduction of azo derivatives containing a naphthalene ring. Reduction is hindered by introduction of a sulfo or carboxyl group into azo derivatives containing a benzene ring.

3. A theoretical explanation of the experimental data on the influence of the sulfo group on the half-wave potential of the investigated compounds is given on the basis of the retarded discharge – ionization theory.

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ORGANOBORON COMPOUNDS

XLV.* THE REACTION OF BUTYL ESTERS OF BORIC AND ORGANOBORIC ACIDS WITH AROMATIC AMINES

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Earlier investigations [1, 2] of the reaction of amines with boric acid esters or their derivatives were mainly concerned with problems of formation of complex compounds. As far as we are aware, only two attempts have been made at direct substitution of alkoxy groups in boric acid esters by the amino group. With this objective a mixture of tributyl borate and dibutylamine was subjected to distillation [3], but the starting substances were recovered. The expected triamine was not isolated when tributyl borate was heated with potassium N-methyl-anilide and the mass then subjected to hydrolysis [4].

We were interested in examining the susceptibility of alkoxy groups of esters of boric acid and their deriva-tives to replacement by the amino group. The work showed that esters of boric acid and of organoboronic acids react with aromatic amines at the boiling point of the latter with formation of the corresponding amino deriva-tives. The reactions are represented by the following equations:

$$B(OC_4H_9)_3 + 3RNH_2 \rightleftarrows B(NHR)_3 + 3C_4H_9OH,$$
$$R'B(OC_4H_9)_2 + 2RNH_2 \rightleftarrows R'B(NHR)_2 + 2C_4H_9OH,$$
$$R_2'BOC_4H_9 + RNH_2 \rightleftarrows R_2'BNHR + C_4H_9OH.$$
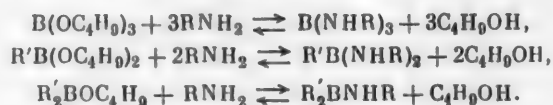
These reactions are reversible, and an ester can only be converted to an amine if the alcohol is removed from the sphere of reaction. The reverse reaction (alcoholysis of the amino derivatives) proceeds at a con-siderably higher speed than the reaction of replacement of alkoxy by the amino group. This was demonstrated in the reaction of phenyldi-(phenylamino) boron $C_6H_5B(NHC_6H_5)_2$ with isobutyl alcohol. If the alcohol was re-moved by distillation from the reaction mixture (this was the method we adopted), the above reactions could be effected only when using an amine whose boiling point was higher than that of the alcohol formed in the reaction.

In this paper we describe the reactions of isobutyl esters of boric, n-propylboric, phenylboric, and diphenyl-boric acids and of n-butyl esters of n-butyl- and di-n-butylboric acids with aniline and p-toluidine. These reactions gave only products of complete substitution of all of the alkoxy groups. The first step in the reaction is probably addition of amine to ester; the resultant complex compounds (I) thereupon split off a molecule of alcohol to form the N-arylaminoesters (II). The latter are known to be unstable [5, 6] and they readily symmetrize.
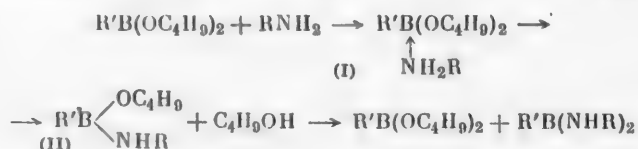
$$R'B(OC_4H_9)_2 + RNH_2 \longrightarrow R'B(OC_4H_9)_2 \longrightarrow$$
$$(I) \qquad \overset{\uparrow}{N}H_2R$$

$$\longrightarrow R'B \overset{OC_4H_9}{\underset{NHR}{<}} + C_4H_9OH \longrightarrow R'B(OC_4H_9)_2 + R'B(NHR)_2$$
$$(II)$$

On comparing the quantities of butyl alcohol evolved during reaction of 0.1 mole $B(OC_4H_9)_3$, $C_6H_5B(OC_4H_9)_2$ and $(C_6H_5)_2BOC_4H_9$ with excess of aniline (see curves 1, 2, and 3 in Fig. 1), we see that both the velocity of formation of 1 mole alcohol from 1 mole ester and the over-all speeds of conversion of esters to amino derivatives increase in the order $B(OC_4H_9)_3 < C_6H_5B(OC_4H_9)_2 < (C_6H_5)_2BOC_4H_9$. Reaction for 4 hours converted 96% of the ester of diphenylboric acid into diphenylphenylaminoboron, whereas reaction for the same period resulted in conversion of only 70% of the ester of phenylboric acid and 38% of the ester of boric acid.

The results show that the rate of replacement of alkoxy groups in esters of boric, phenylboric and diphenylboric acids by arylamino groups is inversely proportional to the rate of hydrolysis [7, 8] of the same esters.
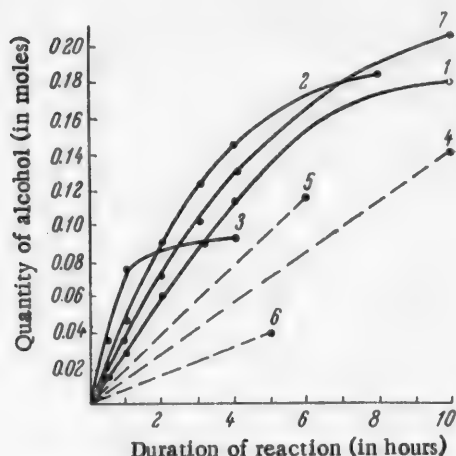
Fig. 1. Reaction of esters with aniline.
1) $B(OC_4H_9)_3$, 2) $C_6H_5B(OC_4H_9)_2$, 3) $(C_6H_5)_2BOC_4H_9$, 4) $n-C_3H_7B(OC_4H_9)_2$, 5) $n-C_4H_9B(OC_4H_9)_2$, 6) $(n-C_4H_9)_2BOC_4H_9$, 7) $B(OC_4H_9)_3$ + p-toluidine.
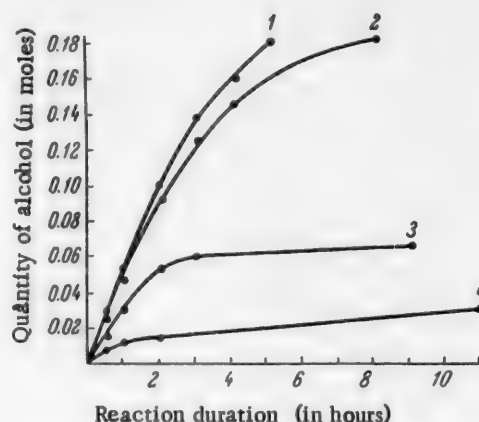
Fig. 2. Reactions of $C_6H_5B(OC_4H_9)_2$ with amines. 1) p-Toluidine, 2) aniline, 3) methylaniline, 4) diphenylamine.

No definite conclusions could be drawn about the speed of the reactions of esters of n-propyl-, n-butyl and di-n-butylboric acids with aniline because in these experiments an appreciable quantity of the original ester was distilled off with the alcohol. Figure 1 therefore shows only the over-all quantity of alcohol given off in the reaction and found on subsequent fractionation of the distilled mixture. Distillative removal of part of the original ester during the reaction accounts for the lower yields of amino derivatives containing alkyl substituents at the boron in comparison with the yields of aryl-substituted derivatives (see table).

The isobutyl ester of n-butylphenylboric acid, which we had previously synthesized [9], was also heated with p-toluidine and aniline. The reaction went relatively quickly, and after 3 hours the theoretical quantity of alcohol was distilled off, but pure substances could not be isolated from the reaction mixture. Under the reaction conditions, the original ester or the amino derivative (reaction product) probably underwent disproportionation. Experiments at lower temperatures in vacuo were impracticable: reaction was substantially nil at 110-120° (100 mm).

The isobutyl ester of phenylboric acid was also reacted with N-methylaniline and diphenylamine with the objective of comparing the reactivities of primary and secondary aromatic amines with esters of organoboron acids. The quantity of alcohol formed when 0.1 mole isobutyl ester of phenylboric acid was reacted with excess of the amines is shown in Fig. 2.

It is seen that secondary aromatic amines react very much more slowly than primary amines. In the experiment with diphenylamine only 15% of the theoretically possible quantity of alcohol was distilled off after 11 hours. The reaction with methylaniline is somewhat faster, 32% of alcohol being formed after 9 hours. Distillation of the reaction mixture gave a liquid with b. p. 127-129° (2 mm) and a solid residue with m. p. 162-_67°. The latter was probably phenyl-bis-(N-methyl N-phenylamino)boron, but it could not be isolated pure. It may be suggested that the liquid product formed during the reaction was the isobutyl ester of phenyl-(N-methyl-N-phenylamino)boric acid which disproportionated on redistillation so that the end product was merely the isobutyl ester of phenylboric acid.

Note should be taken of the great reactivity of p-toluidine in the reactions (in comparison with aniline); this is evident from inspection of curves 1 and 7 in Fig. 1 and curves 1 and 2 in Fig. 2. Phenyldi-(p-tolylamino)-boron is easily transformed into borazole derivatives. For example, heating for 1 hour at 280-295° of the reaction mixture resulting from interaction of the isobutyl ester of phenylboric acid with p-toluidine gives B-triphenyl-N-tri-p-tolylborazole. After crystallization, the latter can be isolated in a yield of 42.5%. As we showed earlier [10], heating of phenyldi-(phenylamino)boron for 1.5 hours at 260-270° converts it into hexaphenyl-borazole in 31.7% yield.

The foregoing results enable us to account for the failure of experiments with tributyl borate and dibutyl-amine [3]. The authors evidently did not take into account the fact that the reaction of a boric acid ester with amines is slow and requires 8 to 10 hours' heating for its completion. In addition, the use of an efficient column would have been necessary due to the relatively small difference between the boiling points of dibutylamine and butyl alcohol (42°).

Concerning the reactions between tributyl borate and potassium N-methylanilide described in [4], we may suggest that the complex compound $[(RO)_3BN(CH_3)C_6H_5]K$ is formed and that this hydrolyzes to boric acid, methylaniline and butyl alcohol.

We observed the formation of an analogous complex compound in the reaction of sodium amide with the isobutyl ester of phenylboric acid. We expected this reaction to lead to phenyldiaminoboron or B-triphenyl-borazole, but we only isolated a precipitate insoluble in benzene, ether and acetone. The compound could not be purified. The analytical data differed from the calculated values, but they revealed the presence of 1 atom of sodium and 1 phenyl group per atom of boron. On the basis of these results we can assign the following structure to the compound:

$$\begin{bmatrix} C_4H_9O \diagdown \\ C_4H_9O \diagup \end{bmatrix} B \begin{matrix} \diagup C_6H_5 \\ \diagdown NH_2 \end{matrix} \Bigg] Na.$$
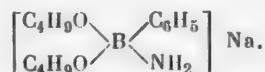
EXPERIMENTAL

Reaction of butyl esters of boric acid and its derivatives with amines. 0.1 mole ester was heated with the amine in a round-bottomed flask equipped with a column (this can be replaced by a Vigreux dephlegmator in experiments with esters of phenyl- and diphenylboric acids). Butyl alcohol began to come over at a bath temperature of 210-220°; the bath was slowly heated to 240-250° and the reaction was stopped when the vapor temperature had reached the boiling point of the original amine. Unreacted amine and ester were distilled off from the reaction mass in vacuo, and the reaction product was later distilled. 30 ml isopentane was added to the slightly warm residue (after removal of the original ester and amine) in the experiments with the iso-butyl ester of phenylboric acid. Crystals gradually appeared. These were filtered and washed with isopentane on the following day. The diamine was further purified by recrystallization from n-hexane. Diphenyl-(phenyl-amino)boron was likewise crystallized from n-hexane. In the experiments with triisobutyl borate, the reaction mixture was immediately recrystallized from 40 ml benzene after the ester and amine had been distilled off. Reaction conditions and results are set forth in the table, together with yields of substances isolated by distillation or by precipitation with isopentane, and yields of the same substances after supplementary distillation or crystalli-zation.

In the reactions with esters of boric, phenylboric and diphenylboric acids, only the pure alcohol came over in the first 4-5 hours of heating. Its purity was checked by the refractive index; later a mixture of alcohol and amine came over; the alcohol content of the mixture was determined by refractionation in a column. In the reactions with esters of alkylboric acids, even the first portions of distillate contained a proportion of original ester, and at the end of the experiment only the total quantity of alcohol formed could be determined. In the experiment with the ester of n-propylboric acid, the residue after distillation of the isobutyl alcohol was treated with 8 ml 25% aqueous sodium hydroxide; the aqueous layer was separated and n-propylboric acid was brought down by acidification with hydrochloric acid. The quantity of the latter was 2.8 g.

Starting substances					Reaction products					
ester (0.1 mole)	amine	Quantity of amine (moles)	Duration of reaction (hour)	Quantity of alcohol distilled off (%)	Formula	yield (%) before purification	yield (%) after purification	Boiling point (pressure in mm)	Melting point	n_D^{20}
B(OC₄H₉-iso)₃	p-Toluidine	0.4	10	70	B(NHC₆H₄CH₃-p)₃ [11]	57	—	—	157–161°	—
C₆H₅B(OC₄H₉-iso)₂ {	Aniline	0.4	8	92	C₆H₅B(NHC₆H₅)₂ [10]	85	63	—	84–86	—
		0.3	5	91	C₆H₅B(NHC₆H₄CH₃-p)₂ *	67	47	—	85–87	—
(C₆H₅)₂BOC₄H₉-iso	Aniline	0.2	4	96	(C₆H₅)₂BNHC₆H₅ **	73	43	202–206°(1)	56–58	1.5837
n-C₃H₇B(OC₄H₉-iso)₂	p-Toluidine	0.4	10	75	n-C₃H₇B(NHC₆H₅)₂ [5]	—	44***	162–163 (1)	—	1.5750
n-C₄H₉B(OC₄H₉-n)₂	"	0.4	6	57	n-C₄H₉B(NHC₆H₅)₂ [5]	32	24	169–171 (1)	—	1.5750
(n-C₄H₉)₂BOC₄H₉-n	"	0.2	5	41	(n-C₄H₉)₂BNHC₆H₅ [12]	38	27	136–137 (7)	—	1.4995

* Found %: C 80.12; H 7.14; B 3.81. C₂₀H₂₄N₂B. Calculated %: C 80.01; H 7.05; B 3.60.

** Diphenyl-(phenylamino)boron was previously prepared by B. M. Mikhailov and N. S. Fedotov from diphenylboron chloride.

*** Calculated on the ester entering into reaction, the yield of diamine is 65%.

Conversion of phenyldi-(p-tolylamino)boron into B-triphenyl-N-tri-p-tolylborazole. Unreacted ester and p-toluidine were distilled off from the mass resulting from reaction of 0.1 mole isobutyl ester of phenylboric acid with 0.3 mole p-toluidine. The residue was heated 1 hour at 280-295° (bath temperature) and 10 mm pressure; 11 g p-toluidine came over. The residue was recrystallized from 100 ml benzene. Yield of recrystallized B-triphenyl-N-tri-p-tolylborazole 8.2 g (42.5%). M.p. 325-327° (after two recrystallizations from benzene).

Found %: C 81.01; H 6.36; B 5.69. C₃₉H₃₆N₃B₃. Calculated %: C 80.87; H 6.26; B 5.60.

Reaction of phenyldi-(phenylamino)boron with isobutyl alcohol. 13.6 g phenyldi-(phenylamino)boron and 9.2 ml isobutyl alcohol were boiled 3 hours and the mixture was then distilled to give 9 g (97%) aniline with b. p. 70-74° (12 mm), n²⁰D 1.5811, and 8.7 g (73.5%) isobutyl ester of phenylboric acid with b. p. 135 to 137° (14 mm), n²⁰D 1.4733.

Reaction of isobutyl ester of phenylboric acid with sodium amide. 13 ml of isobutyl ester of phenylboric acid was stirred at −70° into a solution of sodium amide in liquid ammonia prepared from 1.15 g sodium. The resulting suspension was stirred 30 minutes at −60 to −70° and then heated to room temperature. 100 ml of benzene was added and the precipitate was filtered, washed with benzene and dried in vacuo. Weight of light-grey product 8.2 g.

Found %: C₆H₅ 27.23; Na 7.26; B 3.05. C₁₄H₂₅O₂NBNa. Calculated %: C₆H₅ 28.22; Na 8.41; B 3.96.

For determination of the sodium content, a weighed sample was dissolved in 100 ml water and part of the water was distilled off in the course of 20 minutes with the aim of removing the ammonia. After cooling, the solution was titrated with 0.1 N acid in presence of phenolphthalein. Phenyl groups and boron were determined by the usual method using mercuric chloride.

SUMMARY

1. Esters of boric and organoboric acids react with primary aromatic amines with replacement of butoxyl groups by arylamino groups. This method was used for synthesis of tri-(p-tolylamino)-boron, phenyldi-(phenylamino)boron, phenyldi-

(p-tolylamino)boron, n-propyldi-(phenylamino)boron, n-butyldi-(phenylamino)boron, diphenyl-(phenylamino)-boron, and di-n-butyl-(phenylamino)boron.

2. The speed of reaction of aniline with the esters increases in the order ester of boric acid < ester of phenylboric acid < ester of diphenylboric acid.

3. Secondary aromatic amines react very much more slowly than primary amines with esters of organo-boric acids.

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ORGANOBORON COMPOUNDS

XLVI. DIALKYLBORIC ACIDS AND THEIR DERIVATIVES

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The first representative of the dialkylboric acids — dimethylboric acid — was isolated from the products of hydrolysis of dimethyldiborane [1].

$$(CH_3)_2B_2H_4 + 4H_2O \longrightarrow 4H_2 + B(OH)_3 + (CH_3)_2BOH.$$

Hydrolysis of diethyldiborane and di-n-propyldiborane [2] probably leads to diethyl- and di-n-propylboric acid, but these were not isolated. Later methods of synthesis of esters of dialkylboric acids, of the acids themselves or of their anhydrides were based on various transformations of trialkylborons. For example, the reaction of triethylboron with aldehydes gave a series of esters of diethylboric acid [3]. Saponification of these [4] led to isolation of diethylboric acid itself. It was later found that passage of moist air through tributylboron results in formation of the n-butyl ester of di-n-butylboric acid [5]. Dibutylboric anhydride [6] was obtained by treatment of tributylboron with 48% hydrobromic acid solution. Hydrolysis of di-n-propylboron iodide, obtained by the action of iodine on tri-n-propylboron, gave di-n-propylboric acid [7], which was not isolated in the pure form and was not analyzed.

A series of derivatives of dialkylboric acids has recently been synthesized with the help of organometallic compounds. The action of alkylmagnesium bromides on borates has been investigated [8]. With trimethyl borate the yield of ester of di-n-butylboric acid does not exceed 17% irrespective of the ratio of borate to Grignard reagent. A higher yield (up to 45-47%) can be attained if butylethylene borate is used in this reaction.

$$C_4H_9OB\left\langle\begin{array}{l}O-CH_2\\ \ \ \ \ |\\ O-CH_2\end{array}\right. + 2RMgBr \longrightarrow R_2BOCH_2CH_2OBR_2.$$
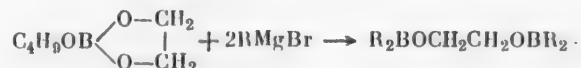
Esters of alkylboric acids can be used for synthesis of esters of dialkylboric acids. Esters of symmetrical as well as unsymmetrical dialkylboric acids can be obtained by this method. Reaction of n-butyllithium or n-propyllithium with the n-butyl ester of n-butylboric acid gave the butyl esters of di-n-butylboric and n-propyl-n-butylboric acids [11].

This method was used in the present work for synthesis of other representatives of esters of unsymmetrical dialkylboric acids — the n-butyl ester of ethyl-n-butylboric acid and the n-butyl ester of ethyl-n-propylboric acid.

$$RB(OC_4H_9)_2 + C_2H_5Li \longrightarrow \underset{R=C_4H_9,\ \ n-C_3H_7}{C_2H_5RBOC_4H_9} + C_4H_9OLi.$$
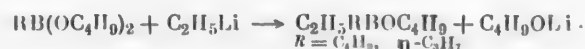
Esters of dialkylboric acids can also be synthesized from esters of alkylboric acids with the help of organomagnesium compounds. Reaction of n-propylmagnesium bromide with the n-butyl ester of n-propylboric acid gave us a 45% yield of the n-butyl ester of di-n-propylboric acid.

$$n\text{-}C_3H_7B(OC_4H_9)_2 + n\text{-}C_3H_7MgBr \longrightarrow (n\text{-}C_3H_7)_2BOC_4H_9.$$

Saponification of esters of dialkylboric acids gives the dialkylboric acids. The resistance of esters of dialkylboric acids to hydrolyzing agents is governed by the nature of the ester grouping. Glycol esters are easily hydrolyzed by caustic alkali at room temperature. The ethylene glycol ester of di-n-butylboric acid was converted into its anhydride without isolation of the acid [8]. Starting from the same ester, we obtained di-n-butylboric acid in the form of a transparent, colorless liquid which is very easily oxidized by oxygen of the air. Di-n-butylboric acid has been described in [10] as a gelatinous, viscous substance, partially crystallizing on standing and melting between 55 and 65°.

n-Butyl esters of dialkylboric acids are very much more resistant to hydrolysis than their glycol esters. In this respect, their behavior resembles that of butyl esters of diarylboric acids [12, 13].

The n-butyl ester of di-n-butylboric acid goes into solution when mixed with 10% aqueous sodium hydroxide solution, and layering takes place. The upper layer is an aqueous solution of the sodium salt of di-n-butylbutoxyborenic acid (I); acidification of the latter gives the original ester

$$(C_4H_9)_2BOC_4H_9 + NaOH \longrightarrow \left[(C_4H_9)_2B\!\!\begin{array}{c} OC_4H_9 \\ OH \end{array}\right]Na \xrightarrow{HCl} (C_4H_9)_2BOC_4H_9. \tag{1}$$
$$(I)$$
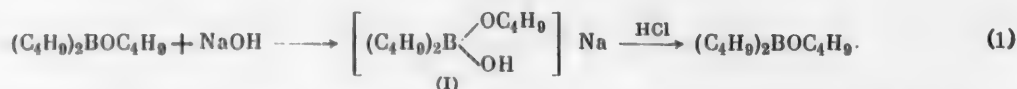
Butyl alcohol comes over with water when the aqueous solution of salt (I) is concentrated by gentle heating in the vacuum of a water jet pump. Complete removal of water and alcohol gives a crystalline residue of the sodium salt of di-n-butylborenic acid (II) in analytical purity. Salt (II) is also obtained when the aqueous solution of salt (I) is dried in a vacuum-desiccator. Compound (I) evidently hydrolyzes in aqueous solution to form the salt of di-n-butylborenic acid and the alcohol. The equilibrium of Eq. (2)

$$(I) + H_2O \rightleftarrows [(C_4H_9)_2B(OH)_2]Na + C_4H_9OH \tag{2}$$
$$(II)$$
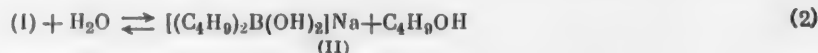
is strongly shifted to the left but with increasing removal of alcohol it is displaced to the right, and the process culminates in formation of the pure salt (II). Esterification of salts of borenic acids of the type of (II), which takes place in equilibrium system (2), was demonstrated by one of us and T. K. Kozminskaya [14] in the case of the lithium salt of α-pyridylborenic acid (III). When the latter is heated with isobutyl alcohol, the hydroxyl groups in the complex anion are esterified with formation of the lithium salt of α-pyridyltriisobutoxyborenic acid (IV).

$$\left[\begin{array}{c}\\ \\ N \end{array}\!\!-\!B(OH)_3\right]Li + 3\,\text{iso-}C_4H_9OH \longrightarrow \left[\begin{array}{c}\\ \\ N \end{array}\!\!-\!B(OC_4H_9)_3\right]Li.$$
$$(III) \qquad\qquad\qquad\qquad (IV)$$
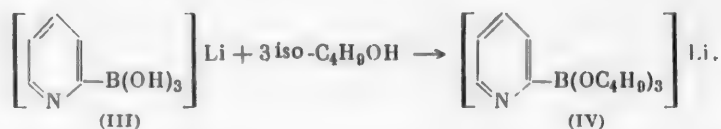
Acidification of salt (II) gives, via intermediate formation of di-n-butylborenic acid (V), di-n-butylboric acid.

$$(II) \xrightarrow{HCl} [(C_4H_9)_2B(OH)_2]H \longrightarrow (C_4H_9)_2BOH.$$
$$(V)$$

Butyl esters of di-n-propylboric and n-propyl-n-butylboric acids are miscible with 10% sodium hydroxide solution in all proportions; acidification of such solutions likewise leads to separation of the original esters, but not of the dialkylboric acids. Conversion of these esters to acids is effected, as in the case of the ester of di-n-butylboric acid, by distillation of water and alcohol from the alkaline solution in vacuo. The resultant dry residue is a mixture of the sodium salt of dialkylborenic acid and alkali. Acidification of the residue, extraction of the aqueous solution with alcohol or isopentane, and distillative removal of the solvent lead to the pure dialkylboric acid.

Di-n-propylboric and n-propyl-n-butylboric acids are colorless liquids, easily convertible into their anhydrides by heating. The anhydride of di-n-propylboric acid was converted to the acid by dissolution in water and subsequent acidification of the alkaline solution.

EXPERIMENTAL

All of the operations with organoboron compounds were performed in a nitrogen atmosphere.

n-Butyl ester of ethylbutylboric acid. In the course of 1.5 hours 96.7 g n-butyl ester of n-butylboric acid dissolved in 100 ml ether was added to an ethereal solution of ethyllithium prepared from 9.70 g lithium, 82 g ethyl bromide and 400 ml ether. During the operation the mixture was gradually cooled from -25 to $-70°$. The reaction mass was stirred for another 3.5 hours and then left to stand overnight. The next day the mixture was saturated with dry hydrogen chloride, and the precipitated lithium salts were filtered off and washed with benzene. Solvents and butyl alcohol were removed from the filtrate in vacuo. More precipitate came down and was filtered off. The residue was fractionally distilled to give the following fractions:

1st fraction: 36.52 g, b. p. 65-67° (7 mm), d_4^{20} 0.7866, n_D^{20} 1.4130.

Found %: C 69.20, 69.05; H 13.58, 13.64; B 6.37, 6.18. $C_{10}H_{23}OB$. Calculated %: C 70.60; H 13.63; B 6.36.

According to the analytical data, this is the n-butyl ester of ethyl-n-butyl boric acid. Yield 50%.

2nd fraction: 19.45 g (20% of the amount taken into the reaction), b. p. 88-94° (7 mm); identical with the original ester of n-butylboric acid.

n-Butyl ester of ethyl-n-propylboric acid. In the course of 1.5 hours, 50 g n-butyl ester of n-propylboric acid diluted with 50 ml ether was added to an ethereal solution of ethyllithium prepared from 4.5 g lithium, 38.1 g ethyl bromide and 250 ml ether. During the operation the mixture was cooled from -25 to $-70°$. The reaction mass was stirred for another 4 hours and then left overnight. The next day the mixture was saturated with dry hydrogen chloride and the precipitate was filtered and washed with isopentane. After the solvents had been removed in vacuo (3 mm), the liquid products were distilled into a receiver cooled to $-70°$ and were then fractionally distilled. Two fractions were obtained:

1st fraction: 12 g, b. p. 82-84° (40 mm), d_4^{20} 0.7748, n_D^{20} 1.4090.

Found %: C 69.19, 69.43; H 13.58, 13.64; B 7.02, 7.06. $C_9H_{21}OB$. Calculated %: C 69.25; H 13.56; B 6.93.

According to the analytical data the first fraction is the n-butyl ester of ethyl-n-propylboric acid. Yield 31%.

2nd fraction: b. p. 124-130° (60 mm), 7.7 g (15.4% of the quantity taken into reaction) is the original n-butyl ester of n-propylboric acid.

n-Butyl ester of di-n-propylboric acid. In the course of 1.5 hours an ethereal solution of propylmagnesium bromide, prepared from 6 g magnesium, 30.2 g n-propyl bromide and 125 ml ether, was added at $-70°$ to 50 g n-butyl ester of n-propylboric acid diluted with 75 ml ether. The mixture was stirred for another 5 hours and then left overnight. The next day, the reaction mass was decomposed with 75 ml 10% hydrochloric acid solution. After the solvent had been driven off, the residue was esterified with 25 ml n-butyl alcohol and then subjected to fractional distillation. Two fractions were collected:

1st fraction: b. p. 76-76.5° (15 mm), d_4^{20} 0.7777, n_D^{20} 1.4133, 19.2 g.

Found %: C 70.40, 70.58; H 13.62, 13.69; B 6.15, 6.29. $C_{10}H_{23}O_2B$. Calculated %: C 70.60; H 13.63; B 6.36.

This fraction is the n-butyl ester of di-n-propylboric acid. Yield 45% (calculated on the original ester).

2nd fraction: b. p. 96-99° (15 mm), 9 g; this is the original ester of n-propylboric acid.

Di-n-butylboric acid. 4.1 g ethylene glycol ester of di-n-butylboric acid [8] was shaken in a separating funnel with 10 ml 10% aqueous sodium hydroxide; the resultant homogeneous solution was acidified with 10 ml of 10% hydrochloric acid, and the organic layer was then extracted with isopentane. The solvent was removed in the vacuum of a water jet pump, and the residue was kept in vacuo (2 mm) until constant in weight (10 mg was lost in 5 minutes). There was obtained 3.4 g (92%) of di-n-butylboric acid; d_4^{20} 0.8105.

Found %: C 67.91, 68.09; H 13.02, 13.18; B 7.46, 7.36. $C_8H_{19}OB$. Calculated %: C 67.67; H 13.48; B 7.63.

Di-n-butylboric acid is a transparent, colorless liquid, very sparingly soluble in water; the acid is very easily oxidized by oxygen of the air.

Action of alkali solution on the n-butyl ester of di-n-butylboric acid. A mixture of 6.9 g n-butyl ester of di-n-butylboric acid and 30 ml 10% aqueous sodium hydroxide was shaken in a separating funnel. The volume of the upper layer increased considerably during the operation; the layer was separated after standing; it weighed 16 g and was analyzed for B and Na. Found %: B 2.32; Na 4.53.

These values corresponded to 6.7 g ester of di-n-butylboric acid and 1.3 g sodium hydroxide. The upper layer was therefore a solution of 0.03 mole sodium salt of di-n-butyl-n-butoxyborenic acid in 8 ml water. The solution was acidified with 10% hydrochloric acid and extracted with ether; after removal of the ether, the residue was distilled in vacuo to give 4.9 g n-butyl ester of di-n-butylboric acid with b. p. 112-116° (20 mm).

Found %: B 5.68, 5.58. $C_{12}H_{27}OB$. Calculated %: B 5.46.

Sodium salt of di-n-butylborenic acid. A mixture of 3.0 g n-butyl ester of di-n-butylboric acid and 15 ml 10% aqueous sodium hydroxide was shaken in a separating funnel; the volume of the upper layer increased considerably. The layer was separated from the lower layer and the water and butyl alcohol were distilled off in the vacuum of a water jet pump. The residual white crystalline substance was the sodium salt of di-n-butylborenic acid; weight 2.3 g (83.5%).

Found %: B 5.64; Na 12.48. $C_8H_{20}O_2NaB$. Calculated %: B 5.94; Na 12.63.

n-Propyl-n-butylboric acid. 5.1 g n-butyl ester of n-propyl-n-butylboric acid was mixed with 12 ml 10% aqueous sodium hydroxide; water and butyl alcohol were distilled off from the resulting homogeneous solution in the vacuum of a water jet pump; the solid residue was thereupon acidified with 15 ml 10% hydrochloric acid and extracted with isopentane. After removal of the solvent, the residual colorless, transparent liquid was kept in a vacuum (3 mm) until constant in weight (3 mg lost after 5 minutes). Yield 2.2 g (62%) of n-propyl-n-butylboric acid, d_4^{20} 0.7986.

Found %: C 65.92, 65.51; H 13.73, 13.16; B 8.72, 8.57. $C_7H_{17}OB$. Calculated %: C 65.66; H 13.38; B 8.45.

Di-n-propylboric anhydride. 8.6 g n-butyl ester of di-n-propylboric acid was dissolved in 20 ml 10% aqueous sodium hydroxide, and water and butyl alcohol were distilled off from the resulting solution in the vacuum of a water jet pump. The solid residue was then dissolved in 20 ml water and acidified with 20 ml 10% hydrochloric acid. The organic layer was extracted with ether, the solvent was driven off, and the residue was dewatered by heating with 20 ml benzene; it was then distilled to give 2.1 g di-n-propylboric anhydride.

B. p. 91.5-92° (10 mm), d_4^{20} 0.7743, n_D^{20} 1.4170.

Found %: C 67.90, 67.96; H 13.21, 13.23; B 10.38, 10.44. $C_{12}H_{28}OB_2$. Calculated %: C 68.63; H 13.44; B 10.31.

· Di-n-propylboric acid. 4.2 g of the anhydride was dissolved in 16 ml of 10% sodium hydroxide solution; the solution was acidified with 20 ml of 10% hydrochloric acid and extracted with isopentane. After removal of solvent, the residue was kept in a vacuum until constant in weight. Yield 3.5 g (77%) of di-n-propylboric acid; d_4^{20} 0.7932, n_D^{20} 1.4108.

Found %: C 63.47, 64.01; H 13.36, 13.37; B 9.33, 8.99. $C_6H_{15}OB$. Calculated %: C 63.21; H 13.26; B 9.49.

Di-n-propylboric acid is a transparent, colorless liquid nearly insoluble in water.

SUMMARY

1. Reaction of ethyllithium with the butyl esters of n-propylboric acid and n-butylboric acids gave the n-butyl esters of ethyl-n-propylboric and ethyl-n-butylboric acids.

2. Reaction of n-propylmagnesium bromide with the n-butyl ester of n-propylboric acid gave the n-butyl ester of di-n-propylboric acid.

3. The n-butyl ester of di-n-butylboric acid forms a complex compound with alkali — the sodium salt of di-n-butylbutoxyborenic acid. The latter was converted into the sodium salt of di-n-butylborenic acid.

Di-n-propylboric, di-n-butylboric and n-propyl-n-butylboric acids and di-n-propylboric anhydride were obtained by hydrolysis of the esters.

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* Original Russian pagination. See C. B. Translation.

RADICAL EXCHANGE IN ORGANOMETALLIC COMPOUNDS

I. EXCHANGE OF ETHYL RADICALS IN THE SYSTEM TETRAETHYLLEAD — ETHYL BROMIDE

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A number of reactions are known in which radicals and positive organic ions move from one molecule to another [1-5]. Radical exchange reactions are also known in the case of organometallic compounds [6, 7]. Calingaert and co-workers [8] studied the mobility of radicals in organolead compounds. It was found that exchange in the system

$$Pb^*(C_2H_5)_4 + (C_2H_5)_3PbCl \rightleftarrows Pb(C_2H_5)_4 + (C_2H_5)_3Pb^*Cl$$

attains equilibrium after 24 hours. The authors showed that exchange reactions take place with many organometallic compounds containing various radicals [9]; they only proceed in presence of additives [10].

Studies of radical exchange reactions provide an insight into the mechanism of chemical reactions. It should be remembered that exchange of like radicals can only be studied by an isotopic method.

Using this method we commenced a systematic study of the exchange of like radicals in various organometallic compounds.

In the present work we studied the possibilities and conditions of exchange of ethyl radicals between tetraethyllead and ethyl bromide labeled with radiocarbon C^{14}. Exchange was studied in photoreactions and in thermal reactions under the influence of some additives in various solvents.

EXPERIMENTAL

Ethyl bromide labeled with C^{14} was prepared by bromination of $1-C^{14}$-ethanol which we had synthesized by the Grignard reaction from methylmagnesium iodide and radioactive carbon dioxide [11].

Commercial tetraethyllead was distilled with steam, dried with anhydrous calcium chloride and fractionated in vacuo. The fraction coming over in the 79-80° range at 13-14 mm was collected.

Additives employed were anhydrous metallic halides [12] and metallic silver (the latter deposited on porcelain pellets).

The solvents were previously dried with anhydrous calcium chloride and fractionally distilled. Fractions corresponding to pure products were collected.

Photoreactions of tetraethyllead with ethyl bromide. Equiradical quantities of tetraethyllead and ethyl bromide were placed in a quartz test tube connected by a ground-glass fitting with a cooling coil to which a

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* N. M. Skvortsov participated in the experimental work.

gas exit tube was attached. The test tube was irradiated by the light from a mercury vapor lamp and cooled with running water. After completion of irradiation, the reaction mass was filtered and fractionated in vacuo. A tetraethyllead fraction with b. p. 79-80° at 13-14 mm was collected. The gases collected in some of the experiments were purified by passage in succession through traps containing ethyl alcohol and concentrated alkali solution. Specimens of tetraethyllead and gases were subjected to radiometric analysis in an internally filled counter [13, 14]. The activity counts were accurate to ± 2%. The collected gases were later subjected to qualitative and quantitative chromatographic analysis.

In order to establish whether or not exchange had occurred, it was necessary to determine whether the tetraethyllead was active. If it proved to be active, then radical exchange must have occurred since a carbon atom alone could not have migrated from ethyl bromide into tetraethyllead. In the event of exchange leading to an equilibrium state, the tetraethyllead would be bound to contain one-fifth of the activity of the original ethyl bromide, since only one of the five radicals in the investigated system contains radiocarbon.

Experimental data show that radical exchange does not take place under the influence of photoirradiation.

Gas analyses showed that the gases consisted of 65% ethane and 35% ethylene and that they exhibited 40-45% of the original activity.

TABLE 1
Exchange of Ethyl Radicals Under the Action of Ultraviolet
Irradiation (Activity of Original Ethyl Bromide 1545 pulses/min;
Activity Calculated on 100% Exchange 309 pulses/min;
Reaction Duration 100 hours)

Expt. No.	Additive	Activity after reaction (pulses/min) of		Exchange (in %)
		$Pb(C_2H_5)_4$	gases	
1	—	None	—	None
2	Silica gel	None	611	None
3	$FeCl_3$	None	603	None
4	$AlBr_3$	None	551	None
5	$AlCl_3$	None	—	None

Thermal Reactions of Tetraethyllead with Ethyl Bromide

Equiradical quantities of tetraethyllead and ethyl bromide were placed in a molybdenum glass ampoule. An additive was also introduced (about 20 mg). The contents of the ampoule were frozen in liquid nitrogen and the air was pumped out. The contents were then unfrozen without access of external air, and then refrozen. The ampoule was exhausted with a rough exhaust pump and sealed. The double freezing and thawing were necessary for complete removal of dissolved oxygen since tetraethyllead can be oxidized by atmospheric oxygen. The sealed ampoule was placed in a steel reactor (hermetically sealable) which was continuously thermostated at 140 ± 1° for 20 hours. After 20 hours, the reactor was removed from the thermostat and cooled to room temperature. Prior to opening, the ampoule was cooled with liquid nitrogen in order to preclude ejection of the liquid by the gases formed in the course of the reaction. Isolation and analysis of the reaction products were carried out as described for photoirradiation.

No exchange resulted from prolonged heating without additives and with additions of silica gel, phosphorus trichloride, cobalt chloride and metallic silver. Analysis of the gases showed them to consist of 76% ethane and 24% ethylene and to exhibit about 40% of the original activity. The smaller proportion of ethylene is probably the consequence of partial polymerization of ethylene under the experimental conditions.

On the other hand, heating of the starting substances to 140° in presence of certain additives (Experiments 6-11, Table 2) caused appreciable exchange (greater than the error of measurement of the activity). It should be noted that the development of activity by tetraethyllead is accompanied by a fall in the activity of the gases from 40- 45 to 20- 25%. This effect is undoubtedly associated with the addition of ferric chloride and aluminum chloride.

It is noteworthy that addition of triethylaluminum (Experiment 10) also causes appreciable exchange. The cause of smaller percentage exchange on addition of triethylaluminum (compared to the exchange in presence of aluminum chloride) is probably radical exchange between ethyl bromide and triethylaluminum which is bound to lower the activity of the tetraethyllead. Exchange by ethyl radicals between ethyl bromide and triethyl-aluminum is detected after a very short time.

TABLE 2

Exchange of Ethyl Radicals on Heating (Activity of Original Ethyl Bromide 5005 pulses/min; Activity Calculated on 100% Exchange 1000 pulses/min)

Expt. No.	Additive	Temperature	Duration (hour)	Activity after reaction (pulses/min) of		Exchange (in %)
				$Pb(C_2H_5)_4$	gases	
1	—			None	1706	None
2	Silica gel			None	—	None
3	$CoCl_2$	140°	20	None	1752	None
4	Ag			None	—	None
5	PCl_3			None	1937	None
6	Dimethylformamide	20	100	31	—	3.1
7	Dimethylformamide			58	—	5.8
8	$FeCl_3$			112	1419	11.2
9	$AlBr_3$	140	20	129	828	12.9
10	$Al(C_2H_5)_3$			161	—	16.1
11	$AlCl_3$			204	822	20.4

It seems to us quite probable that the mechanism of the exchange reaction involves formation of an intermediate complex (capable of ionization) from both of the components of the system and the additives.

TABLE 3

Exchange by Ethyl Radicals on Heating in Nitromethane (Activity of Original Ethyl Bromide 5005 pulses/min; Activity Calculated on 100% Exchange 1000 pulses/min; Reaction Temperature 140°; Reaction Period 20 hours)

Experiment No.	Additive	Activity of $Pb(C_2H_5)_4$ after reaction (in pulses/min)	Exchange (in %)
1	—	50	5.0
2	$CoCl_2$	25	2.5
3	Ag	75	7.5
4	$FeCl_3$	178	17.8
5	$AlBr_3$	190	19.0

A polar solvent ought to influence the extent of exchange if our hypothesis of intermediate complex formation is correct. A more polar solvent should facilitate exchange to a greater extent. We carried out exchange experiments using nitromethane and dimethylformamide as solvents. Dimethylformamide has a higher polarity than nitromethane and it partially ionizes alkyl halides [15].

A polar solvent is seen to promote radical exchanges; this effect is manifested even in presence of additives which had been without any effect in the absence of a solvent (Experiments 3-5, Table 2). This behavior is indicative of an ionic mechanism of the investigated reactions.

TABLE 4

Exchange by Ethyl Radicals on Heating in Dimethylformamide
(Activity of Original Ethyl Bromide 5005 pulses/min; Activity
Calculated on 100% Exchange 1000 pulses/min; Reaction
Temperature 140°; Reaction Period 20 hours)

Experiment No.	Additive	Activity of $Pb(C_2H_5)_4$ after reaction (pulses/min)	Exchange (in %)
1	—	75	7.5
2	$CoCl_2$	45	4.5
3	Ag	130	13.0
4	PCl_3	230	23.0
5	$FeCl_3$	288	28.8
6	$AlBr_3$	303	30.3

The authors wish to thank G. A. Razuvaev for his interest and valuable counsel in this work.

SUMMARY

1. Ethyl radical exchange in the system tetraethyllead — ethyl bromide was studied with the help of C^{14} radiocarbon.

2. No exchange was detected in the system in the absence of additives or under exposure to photochemical treatment.

3. Appreciable exchange, reaching 20%, was caused by small quantities of anhydrous halides of aluminum and iron, also by triethylaluminum and dimethylformamide.

4. It was shown that exchange is intensified in presence of polar solvents.

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STEREOCHEMICAL INVESTIGATIONS

VI. SCHIFF BASES FROM OPTICALLY ACTIVE α-(p-XYLYL)-ETHYLAMINE

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The preceding communications [1, 2] described Schiff bases obtained from optically active α-phenyl-ethylamine and α-benzylethylamine. In continuation of the investigations, we have prepared a series of Schiff bases from optically active α-(p-xylyl)-ethylamine. This compound is interesting in that one of the alkyl radicals is in the immediate vicinity of the asymmetric center — in the ortho position of the aromatic ring.

A study of the optical activity of Schiff bases from α-(p-xylyl)-ethylamine showed that, while broadly resembling the corresponding compounds obtained from α-phenylethylamine, they do exhibit noteworthy differences. The main difference is that the Schiff bases obtained from α-(p-xylyl)-ethylamine are more susceptible to change of rotation in dependence on the solvent than the previously described Schiff bases from α-phenylethylamine. As in the case of the similar strong dependence of the magnitude of rotation observed in previous series, this effect can be associated with the presence of an ortho substituent in the aldehyde ring. We may put forward the working hypothesis that in the case of α-(p-xylyl)-ethylamine this strong dependence is due to the influence of the solvent on the established preferred conformations — in this case due to the change in the relative spatial arrangement of the $o\text{-}CH_3$ group and the $-CH(CH_3)-N=CH-C_6H_4X$ residue.

It can also be noted that the magnitude of the molecular rotation of derivatives of α-(p-xylyl)-ethylamine is usually much smaller than that of derivatives of α-phenylethylamine. The only exceptions to this rule are the two Schiff bases with o-nitro- and o-methoxy groups. In the latter cases, the derivatives of α-(p-xylyl)-ethyl-amine have a higher rotation than the derivatives of α-phenylethylamine. Here again a preferred conformation effect may be postulated — a substituent in the ortho position of the aldehyde ring apparently constrains the amine nucleus with its $o\text{-}CH_3$ group into a position quite different from that in the absence of an ortho substituent in the aldehyde ring.

In other respects, however, the two series of Schiff bases under comparison are extremely similar; in particular, in both series the optical activity rises in the same order depending on the nature of the substituent in the aldehyde ring.

Optically active α-(p-xylyl)-ethylamine was prepared from its racemate via the diastereomeric salts with menthylsulfuric acid as described in Communication II [3]. We were able to achieve better resolution by working with fairly large quantities of the diastereomeric salts and obtained an amine with $[\alpha]^{20}D$ of $+62°$. It may be claimed that complete resolution is achieved because this value of rotatory power was obtained in a series of parallel experiments.

Data for the optically active Schiff bases that were prepared are set forth in the table. All measurements were made at room temperature at a concentration of 2.2-2.4 g per 100 ml solution, except when otherwise indicated in the table. When the starting amine did not possess perfect optical purity, the Schiff base was purified only by distillation since there is a risk of alteration of the optical purity on recrystallization. All the molecular rotation values in the table are recalculated on the basis of optically pure (+)- amine with $[M]^{20}D$ $+93°$.

Schiff Bases Prepared from (+)-α-(p-Xylyl)-ethylamine (CH₃)₂C₆H₃-CH(CH₃)-N=CH-C₆H₄-X

Substituent X	Melting point	Molecular rotation in solvents					Empirical formula	Results of analysis (in %)			Optical purity or original amine (in %)
		benzene	methanol	acetone	dichloro-ethane	heptane		element	found	calculated	
H	liquid	− 80°	0.0°	−104°	− 79°	−173°	$C_{17}H_{19}N$	N	5.79, 5.67	5.90	63.3
o-OH	70.5— 71°	−246*	−196	−223*	−206	−289	$C_{17}H_{19}ON$	C	80.05	80.58	100
								H	7.62	7.55	
p-N(CH₃)₂	108—109	−411	−133*	−373**	−427****	−366	$C_{19}H_{24}N_2$	C	81.62	81.37	26.6
								H	8.81	8.63	
o-NO₂	68.5— 69	+243	+191	+103**	+169	+179**	$C_{17}H_{18}O_2N_2$	N	10.04, 10.21	9.93	100
p-NO₂	79— 80	−225*	−140	−213	−159*	−258	$C_{17}H_{18}O_2N_2$	N	10.11, 10.08	9.93	100
p-CH₃	95.5— 96	− 96***	+ 31	−121	− 66	—	$C_{18}H_{21}N$	N	5.65, 5.69	5.61	26.6
o-OCH₃	69— 71	+160**	+169	+ 70	+ 66	+ 18	$C_{18}H_{21}ON$	N	5.46	5.24	100
p-OCH₃	94.5— 96	−175	− 55	−157	−121	−224****	$C_{18}H_{21}ON$	N	5.26, 5.36	5.24	63.3
p-Cl	91— 92	−159	− 84	−151	−132	−225****	$C_{17}H_{18}NCl$	N	5.07, 5.06	5.15	43.9

* Concentration c = 3.0-2.8.

** Concentration c = 2.6-2.5.

*** Concentration c = 7.2.

**** Concentration c = 1.7-2.0.

Resolution of α-(p-xylyl)-ethylamine into the optical antipodes. To a mechanically stirred solution of 69.5 g (0.79 mole) dioxane in 150 ml dichloroethane was added at 2-4° a solution of 63.0 g (0.79 mole) sulfur trioxide in 200 ml dichloroethane, followed by 123.3 g (0.79 mole) menthol. The initially formed precipitate of dioxane sulfotrioxide dissolved, and the mixture became completely liquid. After 30 minutes, 126 g (0.79 mole) α-(p-xylyl)-ethylamine was added. After 12 hours, the precipitate was filtered and then recrystallized 10 times (each time from 3.5 liters water). There was obtained 32.2 g salt formed by the (+)-amine with menthylsulfuric acid. M. p. 173-175°, $[\alpha]^{20}D$ −36.7° (CH_3OH, 0.3106 g substance in 12.6 g solution). The salt was decomposed with barium hydroxide (17.5 g) and the amine distilled with steam. There was obtained 9.8 g amine with $[\alpha]^{20}D$ + 62.4° (without solvent), d^{20}_4 0.9440 and b. p. 218-221°.

The benzoyl derivative had m. p. 143°.

Found %: C 80.31, 80.44; H 7.69, 7.72; N 5.65, 5.75. $C_{17}H_{19}ON$. Calculated %: C 80.60; H 7.57; N 5.53.

The dichloroethane filtrate was distilled with steam to remove the solvent and a little unreacted menthol; barium hydroxide was added and the distillation was continued. α-(p-Xylyl)-ethylamine was obtained with $[\alpha]^{20}D$ − 45.5° (without solvent).

An amine with varying degrees of optical purity was obtained from the intermediate fractions which accumulated in course of crystallization. After the amine had been steam-distilled, CO_2 was passed through the liquid remaining in the distillation flask until the alkaline reaction to phenolphthalein paper had disappeared; the liquid was then filtered and evaporated to give the barium salt of menthylsulfuric acid which could be used for further resolutions.

Benzylidene-α-(p-xylyl)-ethylamine. To 9 g (0.79 mole) (+)-α-(p-xylyl)-ethylamine was added 6.5 g (0.06 mole) benzaldehyde. The mixture was heated 30 minutes on a water bath; 60 ml benzene was then added and the reaction water was distilled off with the benzene. The residue was vacuum-distilled to give 11.8 g of substance.

B. p. 145-153° (4 mm), d^{20}_4 1.012, $n^{20}D$ 1.5813, MR_D 78.18; Calc. 76.90.

Data for the optical rotation and analytical results for this and other preparations are given in the table.

p-Methoxybenzylidene-α-(p-xylyl)-ethylamine. Prepared from α-(p-xylyl)-ethylamine and anisaldehyde by a procedure similar to that described above. Yield 79.3%. B. p. 180-190° (3 mm).

p-Chlorobenzylidene-α-(p-xylyl)-ethylamine. Prepared from α-(p-xylyl)-ethylamine and p-chloro-benzaldehyde. Yield 83%. B. p. 191-192° (6 mm).

The other Schiff bases listed in the table were similarly prepared from α-(p-xylyl)-ethylamine and the appropriate aldehydes. However, they were purified not by distillation but by recrystallization from methanol. Yield nearly quantitative.

SUMMARY

1. A series of Schiff bases were prepared from optically active α-(p-xylyl)-ethylamine. Their optical activity was studied.

2. In general, substituents in the aldehyde ring exert the same influence on the magnitude of the optical rotation of the resulting Schiff bases as in the case of Schiff bases derived from α-phenylethylamine.

3. The magnitude of the optical rotation of Schiff bases from α-(p-xylyl)-ethylamine varies considerably in dependence on the solvent.

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THE ENTHALPY OF FORMATION OF COMPOUNDS OF CALCIUM WITH
ELEMENTS OF THE MAIN SUBGROUP OF GROUP V

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Preparations of Ca_3Sb_2 and Ca_3Bi_2 needed for the investigation were obtained by fusion of the components in the stoichiometric ratio. Starting materials were high-vacuum-distilled metallic calcium, antimony and bismuth whose spectral analyses indicated the presence of insignificant amounts of other metals. Calcium antimonide was prepared in a corundum crucible placed in a hermetically closed steel bomb at 1300°; calcium bismuthide was prepared in a hermetically closed steel crucible at 1000°.

The free space in the crucible was filled with argon. Analysis of the melts showed that fusion is not accompanied by a change in the ratio of components and that iron and other components of the steel are substantially absent.

Calcium phosphide and arsenide were prepared by prolonged heating of calcium in the vapor of phosphorus and arsenic. The excess of nonmetallic element was distilled off and the preparations were finally heated in vacuo.

The following are the results of analysis of calcium phosphide and arsenide.

Found %: Ca 66.18. Ca_3P_2. Calculated %: Ca 65.99.

Found %: Ca 44.58. Ca_3As_2. Calculated %: Ca 44.52.

The reaction of Ca_3E_2 with 1 N hydrochloric acid was utilized for calorimetric measurements. We have already described the calorimetric procedure [1].

Reactions of calcium phosphide and arsenide are quantitatively expressed by the general equation:

$$Ca_3E_2\,cryst + 6\,HCl_{sol} = 3CaCl_2\,sol + 2EH_3\,gas,$$

where E is phosphorus or arsenic.

Calcium antimonide and bismuthide react with hydrochloric acid according to the general equation:

$$Ca_3E_2\,cryst + 6\,HCl_{sol} = 3CaCl_2\,sol + 2E_{cryst} + 3H_2\,gas.$$

In the calorimeter, calcium antimonide was dissolved not in pure HCl solution but in a solution of the latter in which a small quantity of calcium antimonide had previously been dissolved. The highly dispersed antimony suspended in such a solution is a catalyst for decomposition of the stibine and ensures that the latter will be substantially absent from the evolved hydrogen [2]. The heats of solution of the investigated reactions are presented in the table.

Reaction	Heat of reaction (in kcal/mole)	Mean heat of reaction
$Ca_3P_{2\,cryst} + 6HCl_{sol.} = 3CaCl_{2\,sol.} + 2PH_{3\,gas}$	267.4, 269.9, 268.3	268.5
$Ca_3As_{2\,cryst} + 6HCl_{sol.} = 3CaCl_{2\,sol.} + 2AsH_{3\,gas}$	216.8, 216.5, 214.9	216.1
$Ca_3Sb_{2\,cryst} + 6HCl_{sol.} = 3CaCl_{2\,sol.} + 2Sb_{cryst.}$ $3H_2\,gas$	275.0, 276.3, 274.1, 276.1	275.4
$Ca_3Bi_{2\,cryst} + 6HCl_{sol} = 3CaCl_{2\,sol.} + 2Bi_{cryst} + 3H_{2\,gas}$	313.5, 314.4, 311.8	313.2

The following values for the enthalpies of formation of compounds of calcium with elements of the main subgroup of group V are obtained from the above values in association with the known values of heats of formation of HCl_{sol}, $CaCl_{2\,sol}$ and $PH_{3\,gas}$ [3] and the recently determined heat of formation of arsine [4]:

$$Ca_3P_{2\,cryst}; \Delta H^0 = -125 \pm 1 \quad kcal/mole$$
$$Ca_3As_{2\,cryst}; \Delta H^0 = -138.6 \pm 1 \quad \text{»}$$
$$Ca_3Sb_{2\,cryst}; \Delta H^0 = -114 \pm 1 \quad \text{»}$$
$$Ca_3Bi_{2\,cryst}; \Delta H^0 = -75 \pm 1 \quad \text{»}$$
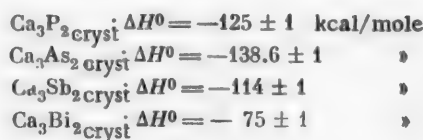
Our value of the enthalpy of formation of calcium phosphide agrees with the value previously proposed by Weibke and Kubaschewski [5] (-120 ± 6 kcal/mole). The magnitudes of enthalpies of formation of calcium antimonide and bismuthide determined in [6] are considerably higher than our values. In an earlier publication [7], we pointed to the fact that the procedure of the authors in question for compounds of very active metals often leads to values of heats of formation which are too high.

The dependence of the heats of formation of compounds of magnesium [2], calcium* and strontium [8-11] with elements of the main subgroup of group V on the atomic numbers of the latter is shown in Fig. 1. We see that although the plot of heats of formation of compounds of magnesium and strontium is reminiscent to some extent of a secondary periodicity, this cannot be said to apply to the plot of heats of formation of the calcium compounds.
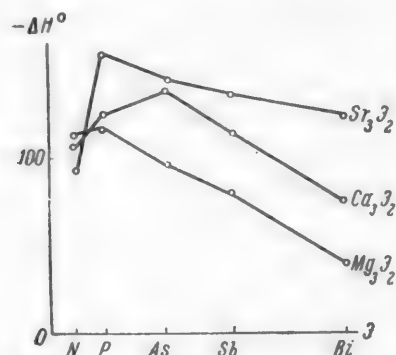
Fig. 1. Dependence of heats of formation of compounds of magnesium, calcium and strontium with elements of the main subgroup of group V (kcal/mole) on the atomic numbers of the latter.
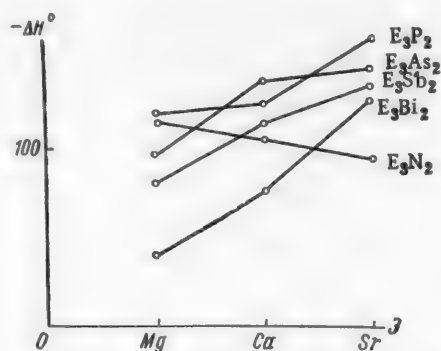
Fig. 2. Heat of formation of compounds of magnesium, calcium, and strontium with elements of the main subgroup of Group V (in kcal/mole).

* The value for Ca_3N_2 is taken from [5].

The difference between the curve for Ca_3E_2 on the one hand and the curves for Mg_3E_2 and Sr_3E_2 on the other hand is governed by the somewhat unexpectedly low value of the heat of formation of Ca_3P_2 (Fig. 2). Moreover, bearing in mind that our value for the ΔH^0 of formation of Ca_3P_2 is close to the value proposed by Weibke and Kubaschewski, this is unlikely to result from experimental errors. The difference in the shapes of the curves of heats of formation of compounds of magnesium, calcium and strontium with elements of the main subgroup of group V versus atomic number may be associated with the circumstance that in the series $E_3P_2-E_3Bi$ for different metals in different periods there is a transition from a predominantly ionic type of bond to a predominantly metallic type.

SUMMARY

1. Values of enthalpies of formation of compounds of calcium with phosphorus, arsenic, antimony and bismuth were determined.

2. It was shown that the plot of heats of formation of compounds of calcium with elements of the main period of the subgroup of group V does not obey the law of secondary periodicity.

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ENTHALPY OF FORMATION OF COMPOUNDS OF SODIUM WITH
ELEMENTS OF THE MAIN SUBGROUP OF GROUP V

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Specimens of Na_3P, Na_3As, Na_3Sb and Na_3Bi were prepared by fusing the components (stoichiometric ratios) in hermetically closed steel crucibles, the free space in which was filled with argon.

Fusion was performed at the following temperatures: Na_3P 500-550°; Na_3As 700°; Na_3Sb 856°; Na_3Bi 775°.
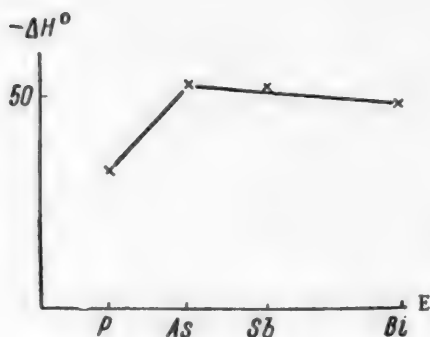
Enthalpies of formation of compounds of sodium with elements of the main subgroup of group V versus the atomic numbers of the latter.

Na_3P was a black powder; Na_3As formed brown-violet crystals; Na_3Sb and Na_3Bi were very brittle, blue-grey or violet-grey substances with a faint metallic luster.

Analysis of the preparations showed that the component ratios are not upset by fusion (to within some tenths of a percent). Iron from the crucible walls entered the preparations in such trace quantities that they could not affect the accuracy of the thermochemical measurements.

For the calorimetric reaction we employed the reaction of the compounds with 1 N hydrochloric acid solution which proceeds quantitatively in accordance with the equations in the table. The procedure for the calorimetric determinations has already been described [1].

The tabulated data in association with the values of the heats of formation of PH_3 gas, $NaCl_{sol}$, HCl_{sol} [2] and AsH_3 gas [3] lead to the following values of heats of formation:

$$Na_3P : \Delta H^0 = -32.0 \pm 1 \quad \text{kcal/mole}$$
$$Na_3As : \Delta H^0 = -52.0 \pm 1 \quad » \quad »$$
$$Na_3Sb : \Delta H^0 = -50.8 \pm 1 \quad » \quad »$$
$$Na_3As : \Delta H^0 = -48.2 \pm 0.5 \, » \quad »$$

The enthalpy of formation of sodium phosphide does not appear to have been previously determined. Our value of the enthalpy of formation of sodium arsenide agrees with the value proposed by Weibke and Kubaschewski [4] (-52.0 ± 6 kcal/mole). The values of enthalpy of formation of Na_3Sb and Na_3Bi obtained by the same authors [4] (47.2 ± 3 and 45.5 ± 3 kcal/mole, respectively) are close to our values.

Heats of formation of compounds of sodium with elements of the main subgroup of group V are plotted against the atomic numbers of the latter elements in the diagram. The heats of formation of compounds of sodium with P, As, Sb, and Bi clearly do not conform to the rule of secondary periodicity; at the same time the plot is not monotonic.

Reaction	Heat of reaction (in kcal/mole)	Mean value
$Na_3P_{cryst} + 3HCl_{sol.} = 3NaCl_{sol.} + PH_{3\,gas}$	149.8, 148.5, 151.1	149.8
$Na_3As_{cryst} + 3HCl_{sol} = 3NaCl_{sol} + AsH_{3\,gas}$	110.7, 109.9, 108.3, 109.3	109.5
$Na_3Sb_{cryst} + 3HCl_{sol} = 3NaCl_{sol} + Sb_{cryst} + {}^3/_2 H_{2\,gas}$	130.2, 128.5, 129.5, 128.4	129.1
$Na_3Bi_{cryst} + 3HCl_{sol} = 3NaCl_{sol} + Bi_{cryst} + {}^3/_2 H_{2\,gas}$	131.2, 131.5, 131.1, 132.4	131.5

SUMMARY

1. Enthalpies of formation of compounds of sodium with phosphorus, arsenic, antimony and bismuth were determined.

2. Although the plot of enthalpies of formation in the series $Na_3P - Na_3As - Na_3Sb - Na_3Bi$ is not monotonic, it does not obey the law of secondary periodicity.

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VOLUMETRIC RELATIONS IN THE SYSTEM VANADIUM — OXYGEN

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Investigations of the volumetric relations in binary systems are of great interest since they often supply quite accurate indications of the boundaries of regions of homogeneity; they also undoubtedly deepen our insight into the very nature of solid phases. To take an example, in the system $Ti-O$ the change in molar volumes indicated an upper limit of the region of homogeneity (the phase poorest in oxygen) at the composition $TiO_{0.48}$ [1], whereas Andersonn [2] fixed the boundary at the composition $TiO_{0.50}$ on the basis of x-ray investigations.

Specimens of vanadium oxides needed for the investigation were prepared by calcination of compacted mixtures of vanadium hydride powder and vanadium trioxide in a high-frequency furnace in high vacuum at 1600° for 3-4 hours. The metallic vanadium used had a content of some tenths of a percent of cobalt. The vanadium trioxide was prepared by reduction of vanadium pentoxide with hydrogen at 900°. The composition of the preparations was checked by determinations of the increase in weight on oxidation to V_2O_5. We have already described [1] the procedure for determination of density by the vacuum-pycnometric method.

Values of densities and molar volumes of lower oxides of vanadium are presented in Table 1. The change in molar volumes is plotted in the diagram.

Composition of preparation	d^{20} (g/cm³)	Molar volume V (cm³/mole)	Composition or preparation	d^{20}(g/cm³)	Molar volume V (cm³/mole)
$VO_{1.70}$	4.57_5	17.1_4	$VO_{1.18}$	6.34_1	13.0_6
$VO_{1.67}$	4.57_3	16.9_1	$VO_{1.09}$	5.44_4	12.5_7
$VO_{1.62}$	4.70_2	16.3_0	$VO_{1.06}$	5.45_0	12.4_5
$VO_{1.50}$	5.01_9	14.9_6	$VO_{1.05}$	5.45_7	12.4_1
$VO_{1.41}$	5.10_0	14.4_2	$VO_{1.03}$	5.46_5	12.3_5
$VO_{1.32}$	5.09_9	14.1_4	$VO_{1.00}$	5.45_2	12.2_9
$VO_{1.28}$	5.14_0	13.9_0	$VO_{0.94}$	5.54_9	11.9_1
$VO_{1.23}$	5.23_0	13.5_0	$VO_{0.90}$	5.59_5	11.6_0
$VO_{1.19}$	5.32_7	13.1_3	$VO_{0.85}$	5.62_0	11.5_0

The first fact to be noted is that the plot of molar volumes against composition indicates an upper limit of the region of homogeneity of the lower oxides of vanadium at the composition $VO_{1.25-1.28}$, whereas our x-ray investigations [3] indicate that the boundary corresponds to $VO_{1.27}$.

At the stoichiometric composition point ($VO_{1.00}$) there is an inflection on the molar volume/composition curve. A similar inflection is found on the enthalpy of formation/composition curve. The same picture is also found in the system $Ti-O$ [1, 4].

It thus appears that, in the terminology of N. S. Kurnakov's school, the curves of molar volumes and enthalpies of formation versus composition indicate that both titanium monoxide and vanadium monoxide are not berthollides (as often assumed) but daltonides.
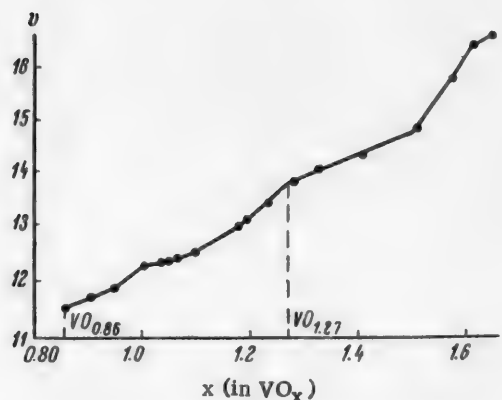
Molar volumes of lower oxides of vanadium (in cm³) as function of composition.

The change of form of the molar volume/composition and enthalpy of formation/composition curves at the stoichiometric point justifies the assumption that the regions $VO_{0.80} - VO_{1.00}$ and $VO_{1.00} - VO_{1.27}$ are two different phases. We previously arrived at a similar conclusion in the case of titanium monoxide [1, 4, 5]. The existence of two phases of lower oxides of titanium and vanadium is in accord with the general ideas put forward by A. V. Storonkin [6].

The molar volumes of substances within the region of homogeneity of titanium monoxide (TiO_{1+x}) are substantially the same as the volumes of mixtures of $TiO_{1.00}$ and $TiO_{1.50}$ (of the same gross composition). As has been indicated, this does not conflict with the hypothesis of the submicroheterogeneous structure of the lattices of lower oxides of variable composition. In the case of the lowest oxide of vanadium, the volumetric relations are more complex: the volume of VO_{1+x} is not equal to the volume of a mixture of $VO_{1.00}$ and $VO_{1.50}$.

We have indicated that the submicroheterogeneous structure in the pure form can be regarded only as a certain limiting case of the chemical structure of lattices of compounds of variable composition; those atoms present in a valence state different from that of the main mass must be distributed in the main lattice in isolated positions. Accordingly, the properties of a compound of variable composition must similarly differ in some degree from the properties of a mixture of the corresponding stoichiometric compounds. Moreover, the segregation of the atoms present in a valence state different from that of the main mass need not necessarily lead to the formation in the region of this segregation of a structure belonging to the compound corresponding to that valence state. In other words, we suggested that the VO_{1+x} lattice contains segregated V^{III} atoms, but we cannot definitely assert that the region of this segregation will be characterized by a structure corresponding to V_2O_3 (the corundum structure). The change in volume when VO_{1+x} is formed from $VO_{1.00}$ and $VO_{1.50}$ may also be explicable in the light of these considerations.

There is no doubt that the volume of a crystalline substance determined on the basis of the density (even under the conditions of the vacuum-pycnometric technique) can also include microscopic (and perhaps even submicroscopic) pores. For this reason, it is sometimes even suggested that the volume of a solid substance as determined by this method cannot generally be used as a basis for assessment of the nature of the phases or of their boundaries. The fallacy of this standpoint is very evident from our experimental data. Indeed, if there had been any serious distortion of the true values of molar volumes due to micropores and if the over-all volume had not been a function of the nature of the solid substance in question (and in turn if the over-all volume had not been constant for a substance of given composition), then the molar volume curve would not have enabled exact determination of the boundaries of the region of homogeneity as was established above.

The impression is created, moreover, that in the case of preparations calcined at a sufficiently high temperature, the density determined by the vacuum-pycnometric technique is sufficiently close to the true density. This is illustrated by the case of vanadium dioxide for which a molar volume of 17.90 cm³ was obtained by the x-ray method and a value of 18.00 cm³ by the pycnometric method (for a preparation calcined at 1600°). Lower densities are found when the specimens are calcined at lower temperatures.

In the case of the vanadium oxide with the stoichiometric composition $VO_{1.00}$ calcined at 1600°, the pycnometrically determined molar volume is clearly higher than the molar volume calculated from x-ray data (by about 17%); we have precisely the same picture with $TiO_{1.00}$ [1, 7]. This can be interpreted as the result of the presence of an equal proportion of vacant sites both in the cationic and the anionic sublattices, or it can be

interpreted as the result of the presence of submicro- or micropores. The first explanation is made more probable by the similar values of density obtained by different authors. It was first suggested by Ehrlich [7]. The second explanation is unsatisfactory because it is difficult to conceive that the volume of the micropores could be so constant.

The following data are given in illustration: The density of an oxide with the composition $TiO_{0.95}$ according to Andersonn [2] is 4.954 g/cm^3 (20°); according to other workers [1] an oxide with the composition $TiO_{1.00}$ has the density of 4.99 g/cm^3 (20°). According to our results, the density of $VO_{1.00}$ is 5.45 g/cm^3 (20°) as compared with Rostoker's value [8] of 5.604 g/cm^3. On the molar volume/composition plot (see diagram) there is a special point at the composition $VO_{1.67}$, in agreement with the x-ray data of Andersonn [2] in support of the existence of a discrete compound of this composition.

SUMMARY

1. The molar volumes of a series of oxides of vanadium were determined. A definite change in molar volume was established as the result of formation of substances with the composition $VO_{1.00}$ - $VO_{1.27}$ from $VO_{1.00}$ and $VO_{1.50}$.

2. Judging by the plot of molar volumes, the upper limit of the region of homogeneity of lower vanadium oxide occurs at $VO_{1.25}$ - $VO_{1.28}$.

3. A special point on the composition/molar volume curve corresponds to the composition $VO_{1.67}$, which is in accord with x-ray data supporting the existence of a discrete compound of this composition.

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COMPOUNDS OF ZINC AND CADMIUM HALIDES WITH N-METHYLANABASINE

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It was previously shown [1] that N-methylanabasine forms compounds with mercury halides of the general compositions $HgГ_2 \cdot 2Alkal$ and $H_2HgГ_4 \cdot Alkal$.

In the present communication we submit the results of a study of the interaction of halides of zinc and cadmium with N-methylanabasine. A comparison is also made between some properties of complex compounds of the zinc subgroup with nicotine, anabasine and N-methylanabasine as determined by us and as reported in [2-8]. This comparison is of general chemical interest since nicotine and anabasine are isomers and N-methyl-anabasine is a methyl derivative of anabasine.

Under similar conditions, halides of zinc and cadmium form compounds with N-methylanabasine of the same type as formed by mercury halides, to wit: $MГ_2 \cdot 2C_{11}H_{16}N_2$ and $H_2MГ_4 \cdot C_{11}H_{16}N_2$.

EXPERIMENTAL

Compounds $MГ_2 \cdot 2C_{11}H_{16}N_2$ can be obtained by two methods. They can be prepared by careful mixing (with energetic stirring) of acetone solutions of the anhydrous zinc or cadmium halide and N-methylanabasine in stoichiometric ratios (very slight excess of N-methylanabasine). In the majority of cases this procedure leads to precipitation of fine, white crystals; these are washed free from N-methylanabasine with acetone on a Schott filter, and dried before being analyzed.

By the second method the halide of zinc or cadmium is dissolved by heating in excess of N-methylanabasine. When cooled, this solution deposits a white precipitate which is filtered and recrystallized from acetone. The zinc or cadmium salt can be used in the form of the crystal hydrates since the water of crystallization evaporates during heating of the reaction mixture.

Compounds $H_2MГ_4 \cdot C_{11}H_{16}N_2$ are easily formed when strongly acidic aqueous solutions of the starting substances in equimolar proportions are carefully mixed and stirred. Subsequent evaporation of the solution leads to deposition of crystals which sometimes possess a reddish tinge. These crystals become colorless after recrystallization in presence of active carbon. Iodides were not recrystallized in presence of carbon because they break down on heating and release iodine. Compounds $H_2MГ_4 \cdot C_{11}H_{16}N_2$ can also be obtained by the action of hydrogen halides on compounds $MГ_2 \cdot 2C_{11}H_{16}N_2$.

Chemically pure grades of N-methylanabasine, $ZnCl_2$, $ZnBr_2$, ZnI_2, $CdCl_2$, $CdBr_2$, CdI_2, HCl, HBr, HI, and acetone were used in the work. Halogens were determined by the Volhard method, zinc and cadmium gravimetrically in the form of $ZnSO_4$ and $CdSO_4$, and N-methylanabasine by titration with acid after steam distillation in presence of Methyl Red.

$ZnCl_2 \cdot 2C_{11}H_{16}N_2$ forms fine, white crystals.

Found %: $C_{11}H_{16}N_2$ 72.01, 72.50; Cl 14.52, 14.34; Zn 13.46, 13.80. $ZnCl_2 \cdot 2C_{11}H_{16}N_2$. Calculated %: $C_{11}H_{16}N_2$ 72.10; Cl 14.51; Zn 13.42.

$ZnBr_2 \cdot 2C_{11}H_{16}N_2$ forms fine, white crystals.

Found %: $C_{11}H_{16}N_2$ 61.09, 61.06; Br 27.45, 27.08; Zn 11.50, 11.49. $ZnBr_2 \cdot 2C_{11}H_{16}N_2$. Calculated %: $C_{11}H_{16}N_2$ 61.00; Br 27.67; Zn 11.32.

$ZnI_2 \cdot 2C_{11}H_{16}N_2$ forms fine, white crystals.

Found %: $C_{11}H_{16}N_2$ 52.58, 52.56; I 37.50, 37.70, 37.55; Zn 9.96, 10.34. $ZnI_2 \cdot 2C_{11}H_{16}N_2$. Calculated %: $C_{11}H_{16}N_2$ 52.46; I 37.80; Zn 9.73.

$CdCl_2 \cdot 2C_{11}H_{16}N_2$ forms fine, white crystals.

Found %: $C_{11}H_{16}N_2$ 65.51, 65.72; Cl 13.48, 13.27, 13.29; Cd 21.00, 20.99, 21.02. $CdCl_2 \cdot 2C_{11}H_{16}N_2$. Calculated %: $C_{11}H_{16}N_2$ 65.79; Cl 13.24; Cd 20.99.

$CdBr_2 \cdot 2C_{11}H_{16}N_2$ forms fine, white crystals.

Found %: $C_{11}H_{16}N_2$ 56.64, 56.79, 56.79; Br 25.55, 25.85, 25.59; Cd 17.79, 17.98, 17.87. $CdBr_2 \cdot 2C_{11}H_{16}N_2$. Calculated %: $C_{11}H_{16}N_2$ 56.40; Br 25.27; Cd 17.99.

$CdI_2 \cdot 2C_{11}H_{16}N_2$ forms fine, white crystals.

Found %: $C_{11}H_{16}N_2$ 48.63, 49.01, 48.95; I 35.55, 35.72, 35.32; Cd 15.55, 15.49, 15.54. $CdI_2 \cdot 2C_{11}H_{16}N_2$. Calculated %: $C_{11}H_{16}N_2$ 49.52; I 35.30; Cd 15.64.

$ZnCl_2 \cdot C_{11}H_{16}N_2 \cdot 2HCl$ forms colorless crystals.

Found %: $C_{11}H_{16}N_2$ 45.55, 45.86; Cl 36.90, 36.64; Zn 16.72, 16.79. $ZnCl_2 \cdot C_{11}H_{16}N_2 \cdot 2HCl$. Calculated %: $C_{11}H_{16}N_2$ 45.73; Cl 36.80; Zn 16.96.

$ZnBr_2 \cdot C_{11}H_{16}N_2 \cdot 2HBr$ forms colorless crystals.

Found %: $C_{11}H_{16}N_2$ 31.25, 31.33; Br 56.63, 56.43; Zn 11.73, 11.96, 11.50. $ZnBr_2 \cdot C_{11}H_{16}N_2 \cdot 2HBr$. Calculated %: $C_{11}H_{16}N_2$ 31.28; Br 56.75; Zn 11.61.

$ZnI_2 \cdot C_{11}H_{16}N_2 \cdot 2HI$ forms colorless crystals.

Found %: $C_{11}H_{16}N_2$ 23.44, 23.38; I 68.28, 67.47; Zn 8.31, 8.90. $ZnI_2 \cdot C_{11}H_{16}N_2 \cdot 2HI$. Calculated %: $C_{11}H_{16}N_2$ 23.46; I 67.57; Zn 8.90.

$CdCl_2 \cdot C_{11}H_{16}N_2 \cdot 2HCl$ forms colorless crystals.

Found %: $C_{11}H_{16}N_2$ 40.59, 40.57, 40.80; Cl 32.64, 32.27; Cd 25.81, 25.95. $CdCl_2 \cdot C_{11}H_{16}N_2 \cdot 2HCl$. Calculated %: $C_{11}H_{16}N_2$ 40.73; Cl 32.80; Cd 26.00.

$CdBr_2 \cdot C_{11}H_{16}N_2 \cdot 2HBr$ forms colorless crystals.

Found %: $C_{11}H_{16}N_2$ 28.62, 29.02; Br 52.25, 52.05, 52.40; Cd 18.82, 18.31. $CdBr_2 \cdot C_{11}H_{16}N_2 \cdot 2HBr$. Calculated %: $C_{11}H_{16}N_2$ 28.06; Br 52.36; Cd 18.42.

$CdI_2 \cdot C_{11}H_{16}N_2 \cdot 2HI$ forms slightly yellowish crystals.

Found %: $C_{11}H_{16}N_2$ 22.11, 22.05; I 63.82, 63.59; Cd 14.01, 14.13, 13.80. $CdI_2 \cdot C_{11}H_{16}N_2 \cdot 2HI$. Calculated %: $C_{11}H_{16}N_2$ 22.06; I 63.59; Cd 14.09.

Melting points of compounds of nicotine and N-methylanabasine with zinc and cadmium halides of the type of $M\Gamma_2 \cdot 2\,Alkal$ are listed in Table 1.

We see from Table 1 that compounds of halides of the zinc subgroup with N-methylanabasine usually melt higher than the corresponding nicotine compounds. Compounds of zinc halides with N-methylanabasine melt higher than the corresponding compounds of cadmium and mercury. Compounds of zinc chloride and bromide with nicotine have a higher melting point than the analogous compounds of nicotine with cadmium chloride and bromide, as well as those with mercuric chloride and bromide. All of the bromides melt higher than the chlorides. The melting points of the compounds of zinc, cadmium, and mercuric iodides with nicotine are approximately identical, while in the N-methylanabasine series they fall in the order zinc, cadmium and mercury.

TABLE 1

Prep. No.	Composition of compound	Melting point	
		nicotine	N-methyl-anabasine
1	$ZnCl_2 \cdot 2Alkal$	138—140°	176—178°
2	$ZnBr_2 \cdot 2Alkal$	148—150	188—190
3	$ZnI_2 \cdot 2Alkal$	125—126	228—230
4	$CdCl_2 \cdot 2Alkal$	90—125	87—88
5	$CdBr_2 \cdot 2Alkal$	135—156	165—170
6	$CdI_2 \cdot 2Alkal$	130°	170—172
7	$HgCl_2 \cdot 2Alkal$	107—110	114—115
8	$HgBr_2 \cdot 2Alkal$	114—117	130—132
9	$HgI_2 \cdot 2Alkal$	127—128	127—129

Note: All of the compounds melt with decomposition.

We also determined the melting points, water solubility, electrical conductivity, and pH of solutions of compounds of zinc and cadmium halides with N-methylanabasine of the type of $H_2M\Gamma_4 \cdot C_{11}H_{16}N_2$ (pH measurements were made at a dilution of 1 mole per 1000 liters at 25°). These results and literature data for corresponding compounds of nicotine and anabasine are presented in Table 2.

We see from Table 2 that the melting points of compounds of the composition $H_2M\Gamma_4 \cdot Alkal$ in the anabasine series are higher than the melting points of the corresponding compounds in the N-methylanabasine and especially the nicotine series. Moreover, the melting points usually rise with increasing atomic number of the halogen, and they fall with increasing atomic number of the metal.

The solubility of compounds with N-methylanabasine is lower than the solubility of the corresponding compounds with nicotine and anabasine; it falls with increasing atomic number of the halogen (an exception is the compound of zinc iodide with N-methylanabasine).

The electrical conductivity of the anabasine compounds is lower than that of the nicotine and N-methylanabasine compounds. The pH and electrical conductivity of the compounds of nicotine, anabasine and N-methylanabasine indicate that these compounds are nearly completely dissociated in aqueous solutions into the original components.

On comparing the melting points of the two types of compounds, we see that they rise in passing from nicotine to N-methylanabasine and anabasine. We may therefore conclude that anabasine is thermally more stable than N-methylanabasine and nicotine. This is in agreement with the literature reports [9] that anabasine is thermally more stable than nicotine and that anabasine derivatives (except N-benzylanabasine) differ from anabasine in being less stable. It must be assumed that the thermal stability of anabasine, N-methylanabasine, nicotine and other alkaloids depends on their molecular structure. For example, the isomers (nicotine and anabasine) consist of uncondensed molecules of pyridine and N-methylpyrrolidine and of pyridine and piperidine which differ in respect of the stability of the molecules that influence the process of complex formation. The latter are the five-membered N-pyrrolidine and the six-membered piperidine ring which enter respectively into the composition of nicotine and anabasine. For example, we failed to isolate complex compounds of nicotine with copper nitrate from acidic aqueous solution in the crystalline form, whereas anabasine under specified conditions easily forms a dark-blue crystalline compound with the same salt [10].

Moreover, the stability of the alkaloids themselves as well as of their complex compounds, and the complex-forming ability of the alkaloids, depend on the nature of the atoms and radicals attached to nitrogen and entering into the composition of the rings. For example, N-methylanabasine (a methyl derivative of anabasine) is less stable than anabasine; the same is true of their complex compounds. It therefore follows that the presence of hydrogen at the nitrogen of the piperidine ring entering into the structure of anabasine has a stabilizing effect on anabasine and its complex compounds which is greater than the effect exerted in N-methylanabasine by the methyl group which replaces the hydrogen at the nitrogen atom of the piperidine ring entering into the structure of N-methylanabasine.

TABLE 2

Serial No.	Composition of compound	Melting point			Solubility (in %)			Electrical conductivity			pH	
		nicotine	N-methyl-anabasine	anabasine	nicotine	N-methyl-anabasine	anabasine	nicotine	N-methyl-anabasine	anabasine	nicotine	N-methyl-anabasine
1	$ZnCl_2 \cdot$ Alkal* $\cdot$ 2HCl	199—202°	253—255°	270°	50.66	20.72	—	620	632	586	3.24	3.28
2	$ZnBr_2 \cdot$ Alkal $\cdot$ 2HBr	214—216	256—258	—	30.10	17.88	—	613	632	—	3.26	3.34
3	$ZnI_2 \cdot$ Alkal $\cdot$ 2HI	237—238	258—260	—	5.70	22.96	—	450	500	571	6.31	3.34
4	$CdCl_2 \cdot$ Alkal $\cdot$ 2HCl	178—180	225—227	259	46.44	30.02	13.79	604	632	596	3.29	3.28
5	$CdBr_2 \cdot$ Alkal $\cdot$ 2HBr	205—208	255—257	292	9.30	4.03	7.41	581	632	527	3.28	3.34
6	$CdI_2 \cdot$ Alkal $\cdot$ 2HI	209—210	235—236	262	0.87	0.56	—	581	632	—	3.80	3.38
7	$HgCl_2 \cdot$ Alkal $\cdot$ 2HCl	162	220—223	255	—	—	0.38	450	437	373	—	—
8	$HgBr_2 \cdot$ Alkal $\cdot$ 2HBr	187	242—245	275	—	—	—	450	413	383	—	—
9	$HgI_2 \cdot$ Alkal $\cdot$ 2H I	180—182	228—230	—	—	—	—	—	—	—	—	—

Alkaloids entering into the composition of the respective compounds

* Alkal = nicotine, anabasine or N-methylanabasine.

It is characteristic that nicotine, anabasine and N-methylanabasine form, under the same reaction conditions, compounds with halides of zinc, cadmium and mercury of one type. This effect is determined by the presence of the nitrogen atoms entering into their structure.

SUMMARY

1. Complex compounds of N-methylanabasine with halides of zinc and cadmium and the corresponding hydrogen halides of the following composition were obtained: $ZnCl_2 \cdot C_{11}H_{16}N_2 \cdot 2HCl$, $ZnBr_2 \cdot C_{11}H_{16}N_2 \cdot 2HBr$, $ZnI_2 \cdot C_{11}H_{16}N_2 \cdot 2HI$, $CdCl_2 \cdot C_{11}H_{16}N_2 \cdot 2HCl$, $CdBr_2 \cdot C_{11}H_{16}N_2 \cdot 2HBr$ and $CdI_2 \cdot C_{11}H_{16}N_2 \cdot 2HI$.

2. The following addition products were prepared: $ZnCl_2 \cdot 2C_{11}H_{16}N_2$, $ZnBr_2 \cdot 2C_{11}H_{16}N_2$, $ZnI_2 \cdot 2C_{11}H_{16}N_2$, $CdCl_2 \cdot 2C_{11}H_{16}N_2$, $CdBr_2 \cdot 2C_{11}H_{16}N_2$ and $CdI_2 \cdot 2C_{11}H_{16}N_2$.

3. The thermal stability of anabasine, N-methylanabasine and nicotine and of their compounds, also their complex-forming ability, depend on the structure of the rings in these alkaloids and on the nature of the atoms and radicals bound to the nitrogen.

4. Nicotine, anabasine, and N-methylanabasine form compounds of identical types with halides of the zinc subgroup under identical conditions.

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LETTERS TO THE EDITOR

THE SEQUENCE OF HYDRATION OF UNSYMMETRICAL DISUBSTITUTED ACETYLENES

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Hydration of monosubstituted acetylenic hydrocarbons, including alkenylacetylenes, under the conditions of the Kucherov reaction gives only methylalkyl- (or alkenyl-)ketones [1-3].

By analogy, vinylalkylacetylenes ought to give alkyl vinyl ketones. However, they add on water preferentially in the reverse sequence with formation of alkyl propenyl ketones [4]. Such a sequence of hydration of vinylalkylacetylenes cannot be explained on the basis of 1,4-addition of water because methylallylacetylene, 1,4-addition of which is no longer possible, forms predominantly 1-hexen-5-one under the same conditions. Nor can the observed sequence of addition be associated with polarization of the molecules of vinylalkylacetylenes under the influence of radicals, since in the case of methylisopropenylacetylene the electron shift under the influence of radicals must be intensified in only one direction, while the sequence of addition unexpectedly changes to the opposite direction: ethyl isopropenyl ketone is unexpectedly formed predominantly. It should be noted that vinylisopropenylacetylene also adds on water in a manner not consistent with a possible shift of the electrons in its molecule [5].

With the objective of establishing the causes governing the direction of hydration of vinyl- and divinyl-acetylenes, we have studied the direction of addition of water to the simplest methylalkylacetylenes under the conditions of the Kucherov reaction. Comparable data on this problem are absent from the literature.

The composition of the mixtures of ketones obtained was evaluated on the basis of comparison of the intensities of the characteristic frequencies in the infrared spectra of the products of hydration with their intensities in the spectra of synthetic mixtures containing a known proportion of each of the expected ketones. The sensitivity of the method was about 2-3%. Results are presented in the table.

$CH_3-C\equiv C-R$ (a) (b)	Ketones expected	Convenient frequencies for analysis of mixtures (cm^{-1})	Content of ketones (%)
$CH_3-C\equiv C-C_2H_5$	$CH_3-CO-C_3H_7$ $C_2H_5-CO-C_2H_5$	1170 1120	42 58
$CH_3-C\equiv C-C_3H_7$	$CH_3-CO-C_4H_9$ $C_2H_5-CO-C_3H_7$	1169 1134	44 56
$CH_3-C\equiv C-CH(CH_3)_2$	$CH_3-CO-CH_2-CH(CH_3)_2$ $C_2H_5-CO-CH(CH_3)_2$	1171 1102	54 46
$CH_3-C\equiv C-C(CH_3)_3$	$CH_3-CO-CH_2-C(CH_3)_3$ $C_2H_5-CO-C(CH_3)_3$	1156 1105	35 65

We see from the table that when identical radicals are attached to the triple bond, hydration results in the oxygen predominantly entering at the C_b carbon. The same sequence of addition is also observed when one radical is primary and the other is tertiary. Predominantly, the opposite sequence of addition is observed when one of the radicals is primary and the other is secondary.

The relation which has been found between the structure of radicals and sequence of hydration indicates that hydration is governed by at least two factors which act in opposite directions. These factors can be inductive polarization of the acetylenic bond and polarization caused by σ, π-conjugation.

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THE SYNTHESIS OF TERTIARY ALIPHATIC HYDRAZINES VIA
MIXED ORGANOMAGNESIUM COMPOUNDS

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Only two successful instances of a Grignard reaction with dialkylhydrazones are known; the reaction of methylmagnesium bromide with formaldehyde dimethylhydrazone and diethylhydrazone in anisole to give dimethylethylhydrazine [1] and triethylhydrazine [2]. The potentialities of this reaction for synthesis of higher tertiary hydrazines remained uncertain. We have studied the reactions of methylmagnesium bromide, ethylmagnesium bromide, propylmagnesium chloride and butylmagnesium bromide with the dialkylhydrazones of formaldehyde, acetaldehyde, propionaldehyde, butyraldehyde and isobutyraldehyde.

0.8 mole of the dialkylhydrazone in 60 ml diisoamyl ether was added to a Grignard reagent prepared from 1 mole alkyl halide in 130 ml diisoamyl ether. The mixture was heated 2 hours on a nearly boiling water bath. The reaction slurry was poured into a mixture of 1 kg ice and 190 ml concentrated hydrochloric acid (d 1.19). The aqueous layer was separated and evaporated to half its volume. After 300 ml 50% sodium hydroxide had then been added, the liquid was distilled until the volatile bases had been completely separated. The distillate was salted out with solid caustic alkali and fractionated in a 15-plate column.

In all cases, the main products (or one of the main products) were tertiary hydrazines. Their physicochemical constants and analytical data are given in the table. Of the 14 trialkylhydrazines synthesized, only two (1 and 14) had previously been known. Storage in loosely closed vessels leads to oxidation by atmospheric oxygen to the corresponding hydrazones with the same carbon skeleton. The yields of hydrazines fall on passage from dimethylhydrazones to diethyl- and dipropylhydrazones. However, the yields remain satisfactory if the alkyl radicals are not very complex, so that the Grignard reaction with dialkylhydrazones can be considered as a general method of preparation of tertiary aliphatic hydrazines.

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* Original Russian pagination. See C. B. Translation.

Trialkylhydrazines Obtained by the Grignard Reaction with Dialkylhydrazones in Diisoamyl Ether

No.	Starting organomagnesium compound	N,N-Dialkyl-N'-alkylhydrazines Name	Empirical formula	Boiling point (pressure in mm)	d_4^{20}	n_D^{20}	MR_D found *	calc. *	Equivalent weight** found	calc.	Nitrogen content by the Dumas method (%) found	(%) calc.	Yield (%)
1	CH₃MgI	Dimethyl-ethylhydrazine	C₄H₁₂N₂	74.9— 75.0° (747)	0.7647	1.4027	28.12	28.19	88.3, 88.8	88.16	—	31.78	75
2	C₂H₅MgBr	Dimethyl-n-propylhydrazine	C₅H₁₄N₂	101.5—101.8 (748)	0.7715	1.4097	32.79	32.84	101.5, 103.1	102.18	27.40, 27.18	27.42	68
3	C₃H₇MgCl	Dimethyl-n-butylhydrazine	C₆H₁₆N₂	127.0—128.0 (748)	0.7800	1.4162	37.41	37.48	116.0, 116.7	116.21	24.02, 23.72	24.11	58
4	C₄H₉MgBr	Dimethyl-sec-butylhydrazine	C₆H₁₆N₂	112.0—112.4 (757)	0.7693	1.4092	37.36	37.48	115.9, 116.8	116.21	23.99, 24.06	24.11	70
5	C₅H₁₁MgBr	Dimethyl-n-amylhydrazine	C₇H₁₈N₂	151.5—152.2 (765)	0.7870	1.4220	42.06	42.14	130.2, 129.6	130.24	21.35, 21.78	21.51	58
6	CH₃MgI	Dimethyl-sec-amylhydrazine	C₇H₁₈N₂	134.7—135.0 (755)	0.7760	1.4155	42.07	42.14	130.4, 130.7	130.24	21.86, 21.31	21.51	66
7	CH₃MgI	Dimethyl-sec-isoamylhydrazine	C₇H₁₈N₂	130.5—131.3 (758)	0.7806	1.4167	41.93	42.14	131.1, 131.9	130.24	21.29, 21.51	21.51	48
8	C₂H₅MgBr	Diethyl-n-propylhydrazine	C₇H₁₈N₂	141.6 (758)	0.7858	1.4196	41.90	42.14	131.5, 130.3	130.24	21.60, 21.77	21.51	31
9	CH₃MgI	Diethyl-isopropylhydrazine	C₇H₁₈N₂	128.7 (769)	0.7739	1.4133	42.00	42.14	129.0, 129.9	130.24	21.41, 21.46	21.51	39
10	CH₃MgI	Diethyl-sec-butylhydrazine	C₈H₂₀N₂	151.5—151.6 (748)	0.7878	1.4218	46.50	46.78	145.0, 146.6	144.26	19.69, 19.38	19.42	42
11	C₄H₉MgBr	Diethyl-n-amylhydrazine	C₉H₂₂N₂	180.0—181.6 (758) 77.7— 78.2 (18)	0.7999	1.4290	51.02	51.43	157.0, 156.5	158.29	17.74, 18.11	17.70	17
12	CH₃MgI	Diethyl-sec-isoamylhydrazine	C₁₀H₂₂N₂	168.6 (751)	0.7963	1.4267	51.87	51.43	156.4, 156.0	158.29	17.43, 17.98	17.70	22
13	C₄H₉MgBr	Diethyl-sec-hexylhydrazine	C₉H₁₂N₂	121.5 (90)	0.7963	1.4297	56.01	56.08	169.4, 174.0	172.32	16.09, 16.39	16.26	31
14	C₂H₅MgBr	Tri-n-propylhydrazine	C₉H₂₃N₂	176.1—177.8 (756)	0.7937	1.4269	51.21	51.43	158.6, 156.5	158.29	17.55, 17.36	17.70	23

* From the refractions of the Vogel bonds.

** By titration with 0.1 N hydrochloric acid using Bromophenol Blue, in aqueous or aqueous alcoholic solution.

Amines are secondary products of the reaction investigated. Formaldehyde diethylhydrazone and dipropyl-hydrazone are characterized by facile scission of the nitrogen — nitrogen bond with formation of large quantities of the corresponding secondary amines. Reaction of formaldehyde diethylhydrazone with butylmagnesium bromide gives a yield of up to 29% of diethylamine. This exceeds the yield of the normal product of addition — the tertiary hydrazine.

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Page	Line	Reads	Should read
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1963	13th from top	$C_{26}H_{16}O_2N_2$	$C_{23}H_{18}O_2N_2$